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Research and Advanced Concepts Office

July 2000



**United States Army Research Institute
for the Behavioral and Social Sciences**

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ARMY RESEARCH INSTITUTE

Program in Basic Research 2000-2001



**Research and Advanced Concepts Office
(RACO)**

July 2000

FOREWORD

If the joy of science is discovery, it is the business of science to communicate these findings. That is the primary concern of this document: to communicate fundamental scientific information about human behavior, which has been generated by the basic research program in the Research and Advanced Concepts Office (RACO) at the United States Army Research Institute for the Behavioral and Social Sciences (ARI). ARI is a directorate of the Total Army Personnel Command and the Army's principal agency for soldier-oriented research and development in personnel and training. Its objective is to maximize Army effectiveness through research and development in the acquisition, training, development, utilization, and retention of Army personnel.

RACO is the locus of an ongoing collaboration between the world of behavioral science and the military community -- an effort that makes available the fruits of fundamental research to behavioral technologists in soldier-oriented R&D. Its aim is to add new knowledge, methodologies, and generalizable principles to many subdisciplines of behavioral science, laying the groundwork for innovative solutions to new and, as yet, unresolved people-related problems of substantial concern to the Army.

RACO sets the stage scientifically for new behavioral technology, facilitating the process by arranging to transfer promising findings to its sister units within ARI for applied research. It is able to bring this about because of its integral position within the ARI structure and within the ARI program. RACO, therefore, acknowledges with special appreciation the role that each of the major research areas of ARI plays in maximizing Army effectiveness through research and development in the acquisition, training, development, utilization, and retention of Army personnel.

Part of a broader RACO effort is to make all of ARI's basic research more accessible to our fellow scientists, the military and academic communities, and others who have serious interests in the progress of behavioral science. It is this objective that provides the purpose of this report: to disseminate knowledge in the best scientific tradition.

The staff of RACO is always available for questions and discussion of our programs. For research reports or more information about RACO's programming, send requests to point of contact, Dr. Michael Drillings at *drillings@ari.army.mil* or call 703-617-8641.



Edgar M. Johnson, Ph.D.
Director, Army Research Institute

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INTRODUCTION

RACO's official research mission is to develop the behavioral science base for future applied research aimed at improving the effectiveness of soldiers and Army systems. It is a way-station between the world of behavioral science and the military community. Searching out and advancing the state-of-the-art methods, theories and findings in behavioral science, encouraging projects most likely to contribute generalizable scientific principles and new knowledge, and supporting those efforts that have potential military relevance and likelihood of leading to behavioral technology are RACO's key research goals.

In RACO's contract programs, a Broad Agency Announcement (BAA) is issued each year to solicit both explanatory proposals (concept papers) and formal proposals relating to the announced program areas. In a given year, the BAA highlights the research objectives of special interest, and provides an open call for proposals.

The reader will find in these pages summaries of current, on-going RACO contracts and in-house projects ranging over the period 1997 - 2000. There are four current RACO program objectives in addition to the continuing search for new insights and scientific breakthroughs. The current objectives are to:

1. Provide fundamental knowledge to improve task training,
2. Provide fundamental knowledge to guide the development and assessment of small team leaders,
3. As the Army evolves from a Cold War force to the 21st century, understand and anticipate the impact of societal trends and changes in the Army and its mission on soldiers,
4. Provide an understanding of cognitive and affective basis of soldier behavior.

This document provides a listing and brief synopsis of ongoing and recently completed research efforts. Project listings are organized into four distinct sections with specific title headings. These headings, described above, reflect RACO's program objectives, and each objective serves as the title for a particular section.

This program, however, is but one of many programs for which RACO has responsibility. Other programs in RACO are:

- Collaboration with the "future Army" programs,
- Small Business Technology Transfer Program,
- International Behavioral Science and Technology Watch,
- Graduate student apprenticeship program - Consortium Research Fellows Program – with the Consortium of Metropolitan Washington Universities,
- Outreach efforts to Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs), and
- Research support in behavioral science for the U.S. Military Academy.

Additional information about reports from these research efforts are available upon request.

We wish to acknowledge the efforts of Consortium Research Fellow Kim Udell, Dr. Jonathan Kaplan, and Dr. David Costanza, in preparing this report.

RACO RESEARCH OBJECTIVE #1:

Provide fundamental knowledge to improve task training.

Research under this heading provide information regarding the development of methods of training that provide improved comprehension of training materials and better long-term retention and generalization of skills.

Enhanced Learning and Retention of Land Navigation and Target Recognition Skills through Equivalence Class Training

Contract #: DASW01-96-K-0009
Institution: Queens College/CUNY

Contract Dates: 6/24/97-7/7/99
PI: Lanny Fields

SCIENTIFIC OBJECTIVES

The scientific objectives of this research were to: (a) identify the pre-training variables that maximize the learning of new equivalence classes while minimizing the instructional resources required for training, (b) identify the variables that influence the formation and breadth of generalized equivalence classes, (c) identify variables that influence the transfer of responding among the members of generalized equivalence classes, and (d) identify methods and procedures that can be used to establish perceptual classes and control their breadth.

An equivalence class is a set of stimuli that function interchangeably even though the stimuli do not resemble each other. An example would be the visual representation of a given aircraft, its infrared signature (IR), its acoustic signature, its technical designations as written and heard, and its nickname as seen and heard. Equivalence class membership also extends to other stimuli that are perceptually similar to the class members, such as distorted images of the aircraft or noisy versions of its acoustic signature. An equivalence class and its related perceptual variants constitute a generalized equivalence class. Actions trained to occur to one class member typically transfer to all remaining members of a generalized equivalence class. To illustrate, if a pilot learns to take a particular action with respect to the name of an enemy airplane, and is then confronted with a novel IR signature that resembles the IR signature for an enemy airplane, the pilot should take the appropriate action. It is possible, however, that the novel IR signature could also be similar to that of a friendly aircraft. If in fact, the novel signature actually represented a friendly aircraft, taking action would lead to a tragic friendly fire accident.

As can be seen from the example, the assignment of a novel stimulus to one or another generalized equivalence class would have a decided impact on the appropriateness of the actions taken by military personnel. These assignments cannot be accounted for by a simple consideration of the perceptual similarity of stimuli because the stimuli in generalized equivalence classes are not perceptually related to many other class members. In the example, the variant of the IR signature was not perceptually related to the name of the aircraft. Rather, the assignment of class membership to a novel stimulus involved higher order levels of cognitive processing. The same argument can be made for many other military tasks. What are the variables that can enhance the correct assignment of novel stimuli to membership to a generalized equivalence class? Answers to that question would have important implications for the training and effective decision making by military personnel when faced with the inevitable variations of training scenarios experienced in field settings.

APPROACH

The participants in our research were college students with cultural and educational backgrounds that match the backgrounds of military personnel. The stimuli used in the experiments are of military relevance: images of terrain landmarks, topographical maps, orienteering symbols, and satellite images of landmasses presented in banded elevation format. Variants of these stimuli were produced either by (a) masking the basal images in a manner that

resembled the addition of cloud cover that shrouded the basal image, or (b) morphing of two basal images to create variants that appeared to be camouflaged versions of the basal images. Matching to sample procedures were used to study the formation of equivalence classes and generalized equivalence classes.

PROGRESS

Our earlier theoretical analysis (Fields & Verhave, 1987) suggested that the structure of equivalence classes and class size should influence the likelihood of equivalence class formation. A number of recent empirical articles suggest that these effects can also be influenced by the level of intellectual function of a subject population. These theoretical predictions were finally confirmed by Fields, Hobbie, Reeve, & Adams (1999) who showed that likelihood of equivalence class formation was an inverse function of class size and was also correlated with the nodal function served by sample and comparison stimuli during training. These effects were not apparent with typically functioning adults in the past because the testing conditions were so easy that the effects of these variables could not be seen. The effects of these variables were made apparent by training classes using the simultaneous protocol and requiring subjects to form relatively large equivalence classes.

In the last two years, we developed a means of identifying the relations among stimuli that come to control behavior. The method called a kernel analysis permits the measurement of momentary changes in the relations among stimuli that control behavior. The kernel analysis was used to measure the pattern and extent of relational responding that existed prior to the equivalence class formation training. We discovered that some patterns of relational responding that were consistent across many subjects was highly predictive of subsequent equivalence class formation and another set of relational responding patterns was highly predictive of subsequent failure to formation equivalence classes. This information provides important insights into the prerequisite repertoires that are needed for successful equivalence class formation. If missing, the prerequisite repertoires could be trained. Thereafter, equivalence classes should become essentially insured. This information, then, should also be of importance for the development of more effective means of teaching equivalence classes of military relevance.

Prior research has involved empirical investigations of generalized equivalence classes. The results of that research have led me to develop a theoretical framework that integrate generalized equivalence classes, linked perceptual classes, and intersensory integration. It has also led to the development of three types of measures that are needed to document the existence and extent of all of these stimulus classes. The results of these theoretical developments then are now directing the development of methodologies that will enable us to fully understand the variables that influence the development of these classes and their extent. That information will be of value since it will permit individuals to be trained in a manner that will enhance appropriate performance in novel settings.

Reeve and Fields (accepted) developed a new procedure for inducing and controlling the breadth of perceptual classes that consisted of stimuli arrayed along very simple dimensions. Perceptual classes that are much more complex, e.g., variants of satellite images that are produced by masking or morphing, are the types of classes that would be of significance to military performances. This year, then, we determined that the forced choice generalization testing procedures used by Reeve and Fields would also be used to induce perceptual classes that consist of variants of satellite images. Thus, perceptual classes that are of military significance

can be established using this new technology. The generality of the method also raises theoretical questions regarding the mechanisms that are responsible for the formation of perceptual categories.

Generalized equivalence classes consist of disparate stimuli that function as members of a basal equivalence class and variants of at least one member of that basal class. The theoretical analysis mentioned above showed that the identification of the variants that function as members of the generalized equivalence class requires the use of generalization tests conducted in two different formats: variant to base and base to variant. This year we found that the range of variants that functioned as members of the same nominal class differed with testing format. The theoretical basis for that difference is not yet known.

Finally, a generalized equivalence class can contain variants of all stimuli that are members of the basal equivalence class. This implies that the variants of one basal class member would have to be related to the variants of all other basal class members. If the basal equivalence class consists of A, B, and C, and the variants of these stimuli are represented by A, B, and C. The variants of A should be related to the variants of B and C, etc. No tests existed for measuring these relations. In the last year, we developed tests to assess these variant-to-variant relations using a simplified behavioral preparation. Thus, it is now possible to fully document the range of stimuli in fully elaborated generalized equivalence classes. Those measurement procedures, then, also provide the basis for the discovery of the variables that influence the likelihood of forming these classes and of controlling their extent. That information is of substantial theoretical importance since it would lead to an operational account of the formation of the complex categories that emerge in natural settings. That information is of applied importance since it would clarify how to reliably establish these categories that are of military significance.

CONTRIBUTIONS TO BASIC SCIENCE

The discovery of the variables that influenced likelihood of forming generalized equivalence classes provides a basis for the understanding the processes responsible for the development of the conceptual categories that influence large ranges of human behavior in the natural environment.

POTENTIAL APPLICATIONS

As mentioned above, many skills required of military personnel involve the correct assignment of ambiguous information to one category or another. The category assignment will dictate the action to be taken. In many cases, those assignments cannot be based on physical similarity of the current situation and prior situations experienced in training. The problem is the same as that faced when subjects have to assign novel stimuli to membership of generalized equivalence classes. Given the similarity of conditions, the results of the research could be used to train personnel to make such assignments in an accurate manner in field settings.

Human Self-Assessment in Training and Testing

Contract #: N68171-96-C-9049
Institution: Stockholm University

Contract Dates: 11/96-06/99
PI: Peter Hassmen

SCIENTIFIC OBJECTIVES

The goal of this project was to gain a better understanding of the relationship between retention and cognitive processing and its interaction with gender. Two experiments addressed this goal. The objective of the first experiment, was to compare men and women's performance on a multiple-choice test and their self-assessment of confidence for each correct answer made, in order to test the effect of self-assessment and investigate the dissimilarities observed between and within their test scores. In addition, the influence of gender-typing on test scores and self-assessments was examined to reveal some of the effects of culturally mandated norms for men and women. The objective of the second experiment, was to test for a systematic relationship between a person's level of confidence in the correctness of their answers and how well the tested material was retained after specified time intervals.

APPROACH

In the first experiment, an equal number of males and females were tested in the United States and in Sweden. In addition to answering the multiple-choice questions, each participant completed the Bem Sex Role Inventory, which was used as a measure to discriminate between gender-typed and non-gender-typed individuals.

In the second experiment, participants were assigned to one of two experimental groups, one group making self-assessments and one group not making self-assessments. The groups were balanced with respect to the number of males and females. Learning and retention were measured by the number of correct items on a multiple-choice test. The participants were tested for retention after one week, six weeks, and twelve weeks.

Data in both experiments were analyzed by analysis of covariance and multivariate analysis of variance. In the second experiment, inter-individual variation among the male participants was compared with the inter-individual variation among the female participants.

PROGRESS

Data collection has been completed for both the multiple-choice study as well as the retention study. Results from the multiple-choice study indicated that differences between men and women were the greatest on the test measuring numerical, problem-solving, and reasoning capabilities with men performing significantly better than women. Further, small and non-significant differences were observed between men and women on the sub-test measuring verbal ability.

Results from the retention study indicated that the length of the retention interval, affected the number of items remembered correctly, and the rate of forgetting, was found to be fairly linear for both men and women. In addition, data from men and women's level of sureness about their correctness of learned responses and how well the material was retained revealed men were more inclined than women to state that they were "extremely sure" both when they were correct and when they were incorrect. This finding confirmed previous research that women were better at acknowledging their lack of sureness and were more accurate in their level of

sureness corresponding to their actual performance than men. Further women who were gender-typed as having masculine characteristics were found to be the most inclined of the women to express themselves as being “extremely sure,” demonstrating that self-confidence and sureness are still gender-typed as male attributes.

A revised manuscript reporting these findings has been resubmitted to the *Journal of Educational Psychology* (entitled: “Performance on the Swedish scholastic aptitude test: Effects of self-assessment and gender”). Additionally, a second manuscript reporting this data has been submitted for publication to the *Journal of Educational Psychology* (entitled: “Effects of self-assessment on acquisition rate and retention in rule-based learning”).

CONTRIBUTIONS TO BASIC SCIENCE

The experiments provided valuable data toward theories which (a) relate retention of learned material after specified time intervals to self-assessment, and (b) relate the extent which differences may be attributed to gender-role and offered new insight as to why men and women perform differently on tests (i.e., multiple-choice).

POTENTIAL APPLICATIONS

By incorporating confidence ratings during all types of training and by including a measurement of gender type, it will be possible to identify those individuals at risk of becoming overconfident in situations where their behavior can result in dangerous mishaps because their confidence is based on misinformed knowledge. Since overconfidence is a fairly common characteristic of both men and women, early identification of problem individuals may save both dollars and human lives in the long run. The self-assessment method examined, offers the trainer an easy way of identifying overconfident individuals, regardless of gender, early in training and enables feedback so that calibration may take place. In addition, through gaining an understanding of gender differences involved in the self-assessment of learning and the perceptual influence of gender-typing, our study has the potential to aid in the improvement of training efficiency and the reduction of training costs.

Optimizing the Durability and Generalizability of Knowledge and Skills

Contract #: DASW01-96-K-0010
Institution: University of Colorado

Contract Dates: 8/2/96–2/1/00
PIs: Alice F. Healy & Lyle E. Bourne, Jr.

SCIENTIFIC OBJECTIVES

The main focus of this research is on enhancing the generalizability, or transferability, of what is learned and retained in a variety of naturalistic and laboratory tasks. This new direction is prompted by two main outcomes of earlier studies. First, we found that durability of how well knowledge and skills are retained in certain domains can be facilitated by procedural reinstatement, which occurs when testing duplicate training procedures. Second, we found the more durable the memory for a certain kind of knowledge or skill, the less generalizable it is beyond the circumstances in which training took place. Thus, we discovered training conditions that promote durable memory but constrain generalizability. In our current work, we are trying to discover ways of promoting the generalizability of those durable memories without sacrificing their durability.

APPROACH

The specific issues that we are addressing include: (a) variations in contextual interference as a means to promote durability and generalizability of knowledge and skills, (b) the relationship between the learning of examples and the learning of rules in conceptual tasks, (c) types of strategies and strategy transitions in category learning tasks, (d) the durability and use of general and specific knowledge in quantitative estimation, (e) communication about navigating in space, (f) response execution in a spatial array, (g) the underlying causes of durability and specificity in digital data entry, and (h) managing rapidly presented information.

PROGRESS

The following are our findings concerning the above issues, their implications for training, and our current and planned follow-up investigations:

Variations in contextual interference as a means to promote durability and generalizability of knowledge and skills. Our findings in two experiments were in accordance with predictions based on Battig's (1972, 1979) contextual interference principle. The findings imply that blocking material by category, which is frequently done in many types of training, may aid initial acquisition but may not yield optimal retention. If durable retention is the goal, contextual interference during training is advisable. In a third experiment, we found that increasing task difficulty during study aided transfer to a new task as well as long-term retention of the original task. The implication for training is that enhancing the difficulty of training exercises will lead to improved retention and transfer. In our future research, we plan to explore this phenomenon further by examining different methods for enhancing task difficulty during training.

Communication about navigating in space. We found that participants' ability to repeat back and follow navigational instructions is affected by the length of the message and two aspects of the participants' mental representation of the space through which they are navigating. First, there was a decrement in performance when the participants had to move outside the picture plane.

Second, there was a decrement in performance when the space was described as involving three dimensions. The implication for training is that additional practice should be given whenever a navigational task requires a three-dimensional mental representation, rather than simply a two-dimensional representation, or whenever the task involves movement along a plane not immediately shown. Our results imply further that three-dimensional displays, such as those found in virtual reality environments, are not sufficient to eliminate the need for this additional practice.

Response execution in a spatial array. We found that the simple task of response execution improved considerably with training, that both the identity and the location of the target affected speed of response, and that two component response time measures (initiation and movement time) showed quite different patterns of results. These different patterns force us to conclude that there are two distinct processing stages involved in simple response execution. The implications are that the two components of response execution can be affected differently by training variables and may differ in their durability over time and generalizability over transfer conditions. Hence, any program that aims to maximize the efficiency of response execution must be sensitive to possible differential effects on these two components.

The underlying causes of durability and specificity in digital data entry. We found a superiority of training with words even when the word format at training was faster than the numeral format because participants were required to type the initial letter of the numbers rather than the digits. We conclude that the superiority of training with words is due to the fact that the word format at training leads to greater processing than does the numeral format. The implication for training is that using a format that forces greater processing should be encouraged whenever possible to promote durability and transferability.

The relationship between the learning of examples and the learning of rules in conceptual tasks. We found strong support for the rote-and-analogy paradigm, as opposed to the rule-and-category paradigm. Individuals' knowledge of the definite article pronunciation (/DUC/ versus /Di/) distinction, unlike their knowledge of the indefinite article (a/an) distinction, does not conform exactly to the simple, general abstract rule included in the dictionary, but is rather more complex and involves information at various levels of abstraction. The implication for training is that individuals do learn complex rules involving different levels of abstraction when given sufficient specific examples but that they also benefit from explicit visual cues, reinforcement, and instruction concerning abstract, general rules. In our future research, we plan to examine the learning of novel linguistic rules so that we can develop general principles concerning the factors influencing the generalizability of known categories to new ones.

Types of strategies and strategy transitions in category learning tasks. We found that monotonic changes in overall measures of performance during practice masked the complexity of changes in the learner's basis of response or strategies employed. The implications for training are that instructors should monitor not only overall measures of performance but also the strategy employed by the trainee. When the most effective strategies are known, instructors would be advised to adopt procedures that can effectively bring these strategies forward earlier than usual

in the training process. In our planned follow-up research, we seek to determine the role of prior knowledge in strategy selection.

The durability and use of general and specific knowledge in quantitative estimation. We found that providing seeding facts, or training with a very small amount of general or specific information, led to large improvements in participants' quantitative estimation skills. The implications for training are that seeding should be used wherever possible when quantitative estimation is required. In our future experiments, we plan to assess retention of quantitative estimation skills by exploring further the durability of improvements due to seeding. We also intend to examine the effects of seeding in other types of skills.

Managing rapidly presented information. We found that participants with no prior knowledge who trained at a fast speed showed worse performance than those who trained at normal or slow speeds. There was no difference between the normal and slow speed groups. The implication is that high-speed training is not recommended for language learning at least for introductory students. More generally, these results imply that training with normal speeds leads to performance at least as good as training with slow speeds and better than training with fast speeds, even when testing is done with a fast speed.

CONTRIBUTIONS TO BASIC SCIENCE

The many research directions we have described here address a diverse set of issues. Nonetheless, they share the common theoretical goal of understanding the psychological principles underlying the acquisition, retention, and most importantly transfer of knowledge and skills. For example, we have proposed a procedural reinstatement principle according to which durable but specific retention results when the procedures, or operations, employed during acquisition are reinstated, or duplicated, at the time of the retention test. This principle has been shown to hold over a wide variety of task domains. We are presently beginning to uncover parallel principles that govern transfer and the generalizability of knowledge and skills.

POTENTIAL APPLICATIONS

Our research is aimed at developing methods for optimizing the durability and generalizability of knowledge and skills. The need for such methods is particularly crucial to military tasks because there is often a long delay between training and encountering applications in the field. In addition, training circumstances can rarely capture the full set of circumstances under which these tasks are encountered in the field. The Army has come to rely increasingly on the use of distributed interactive simulation and virtual reality as training mechanisms. Although these novel procedures seem likely to be effective, it is not yet clear how durable and generalizable the knowledge and skills acquired under these procedures will be beyond the training environment. The goal of our current research is to develop general training principles relevant to the integration and coordination of skills for optimal performance in naturalistic military environments.

Optimizing the Speed, Durability, and Transferability of Training

Contract #: DASW01-99-K-0002
Institution: University of Colorado

Contract Dates: 8/1/99–7/31/02
PIs: Alice F. Healy & Lyle E. Bourne, Jr.

SCIENTIFIC OBJECTIVES

The U.S. Army spends ample time and resources in training its personnel. Training is essential because recruits cannot be expected to come equipped with the military knowledge and skills they will need in the field. But such training is also costly, so it is important to ensure that it be accomplished as quickly and as efficiently as possible. Increasing training speed, however, should not be the only or even the most important consideration. If soldiers have successfully learned how to perform a task during training but then forget how to perform it at the time that they need to do so, the training has clearly been inadequate. Passing a test at the end of training does not guarantee later success in the field. Training needs to be durable as well as efficient. But even durable training cannot guarantee that learned knowledge and skills will be applied successfully to situations different from those encountered during training. Tasks encountered during training circumstances can rarely capture the full set of circumstances of tasks encountered in the field. It is, therefore, essential that training be transferable as well as durable. Thus, it is the aim of our research program to develop principles that separately optimize the three major aspects of training: (a) its speed or efficiency, (b) its durability or long-term retention, and (c) its transferability or generalizability to new situations.

APPROACH

Although many of our studies have overlapping goals, for present purposes we have divided them into three major groups. The first group is principally concerned with managing factual overload, rapidly presented information, stress, frustration, and fatigue, with an emphasis on tasks involving perceptual and motor processing. The second group addresses the comprehension of verbal and spatial information. The last group is primarily addressed to a consideration of optimizing the balance of the three major aspects of training.

Studies in the group on managing factual overload, rapidly presented information, stress, frustration, and fatigue focus on the following four issues: (a) handling factual overload, (b) dealing with rapidly presented information, (c) initiating and executing responses under stress and frustration, and (d) initiating and executing response components under fatigue produced by prolonged work. Studies in the group on comprehension of verbal and spatial information focus on the following four issues: (a) how the mental representation of space affects comprehending directions about navigating within that space, (b) the retention and transfer of the skills involved in comprehending navigation directions, (c) the relationship between the verbal and spatial representations of navigation directions, and (d) the effects of overload on the comprehension of navigation instructions. Studies in the group on balancing the three major aspects of training focus on the following four issues: (a) the sources of specificity during training and transfer, (b) variations in contextual interference and task difficulty as a means to promote durability and transferability of training, (c) types of strategies and strategy transitions during training, retention, and transfer, and (d) seeding the knowledge base with a minimal set of facts.

PROGRESS

Progress has been made on all three groups of experiments. We concentrate this summary on three studies completed during this period, one study from each group.

Managing factual overload, rapidly presented information, stress, frustration, and fatigue.

Research on expertise and research on verbal learning offer different predictions for how participants will perform during learning and memory tasks involving factual overload. We found in Experiment 1 that participants showed superior learning and recall of a large quantity of new, discrete, non-domain relevant facts about concepts within their domain of high knowledge than about concepts for which they had low domain knowledge. Experiment 2 investigated whether the participants' superior recall of new facts related to concepts within their domain of high knowledge was due to the number of prior facts associated with the concepts or to the prior frequency of repetition of those concepts. We found that participants' recall of new facts was better for concepts with five prior associated facts than for concepts with a single prior association, but the number of previous repetitions of each associated fact did not affect the level of recall for the new facts.

Comprehension of verbal and spatial information. We have developed a laboratory analog of communication between air traffic controllers and pilots. In our laboratory task, participants hear directions like those given by air traffic controllers; they repeat the directions aloud, as pilots are expected to do; and then they follow the directions, navigating in the space displayed on the computer. We have completed an experiment aimed at testing the effects on comprehension of the modality of message presentation. In the standard version of the experimental paradigm and in the ordinary air-traffic-control communication situation, the messages are presented in the auditory modality. However, with new technology the visual modality could be used instead, and the modality used may influence the participants' ability to comprehend, remember, and carry out the commands in the message. Hence, we compared visual and auditory presentation of messages. The participants in each condition were subdivided into two groups, a read-back group, which repeated aloud the directions before following them, and a no read-back group, which did not. We found that read-back condition, despite the fact that it probably created output interference, did help with the auditory modality but only when short messages were repeated. It typically did not help with the visual modality presumably because of the re-coding, from visual to phonological input, required in that case. Thus, when messages are short enough, the ordinary pilot procedure of reading back may indeed be helpful. Determining the effects of message read-back on performance is of practical significance because the potential benefits in insuring that pilots have fully understood directions from air traffic controllers may trade off with the possible costs in interfering with the pilots' memory for the directions.

Balancing the three major aspects of training. Two sessions were conducted in each of the two experiments. In the initial session, participants were given three trials of training on French-English vocabulary pairs and then were tested on these pairs. In the second session, a week later, participants were re-tested and then retrained on the same pairs. Both English-French and French-English translation directions were employed. In Experiment 1, the vocabulary pairs were either blocked or not blocked by category, and in Experiment 2, participants were pre-trained on half of the French words before vocabulary learning. Translation direction, blocking,

and pre-training all had opposite effects in the two sessions, with accuracy being higher in the first session but equal or lower in the second session when initial learning involved the French-English translation direction, blocked pairs, and pre-training on French words. These effects are interpreted in terms of the principle of contextual interference within a paired associate learning framework.

CONTRIBUTIONS TO BASIC SCIENCE

Through these three studies we expect to elucidate a common theoretical understanding of the psychological principles underlying the acquisition, retention, and generalization of knowledge and skills. The research directions we are taking explore the question of how individuals optimize their speed, durability, and transferability of learned information when subjected to stressful, overwhelming, and fatigue-inducing conditions. Current efforts are aimed at understanding the context and conditions for transfer, comprehension of verbal and spatial information, and the management of the learned information under stressful performance conditions. These efforts will contribute to attempts at identifying the psychological principles and contexts of effective learning, from an analytic and experimental approach, to aid in further development of effective training methods to overcome the degradation of information over time.

POTENTIAL APPLICATIONS

These studies also share the common applied goal of improving the training of military personnel such that the knowledge and skills will be acquired quickly and yet still be accessible across long delay intervals with no practice and adaptable to new situations outside the training environment. The balance of the three aspects of training (speed, durability, and transferability) is not necessarily fixed across or within tasks and may depend on a variety of external factors, such as stress, frustration, fatigue, speed of information presentation, and information load, which can change from time to time. Variations in any one of these factors can affect the interaction of these aspects of training. Hence, our studies also examine the three aspects of training under various conditions of stress, frustration, fatigue, speed of information presentation, and information load. This examination should help with designing training programs that will allow the trainee to contend with these external conditions that obtain unpredictably in the field and could adversely influence performance if not properly managed.

Individual Differences in Environmental Spatial Cognition

Contract #: DASW01-95-K-0014

Institution: University of California, Santa

Barbara

Contract Dates: 9/95-3/00

PIs: Mary Hegarty & Daniel R. Montello

SCIENTIFIC OBJECTIVES

The scientific objectives of this project are: (a) to identify dimensions of environmental spatial abilities and to develop valid and reliable measures of these abilities; (b) to investigate how environmental spatial abilities (i.e., spatial and navigational ability in the real-world) are related to more traditional psychometric measures of cognitive abilities and to people's self-reports of their own abilities; and (c) to study how environmental spatial abilities differ as a function of scale of space, whether people are navigating in real or simulated space, the amount of dynamic processing of space involved in a task, and the complexity of the space.

APPROACH

We used a combination of correlational and experimental methodologies. In a large correlational study, we collected data from over 220 participants on several measures of environmental and more traditional spatial abilities. We analyzed this data to reveal the factor structure of environmental spatial ability and how environmental spatial abilities are related to other psychometric and self-report measures. We have also conducted smaller correlational studies investigating static and dynamic spatial abilities at different scales and abilities related to production of verbal navigation instructions.

In addition, we have conducted a number of experimental studies that measure the effects of different factors on spatial performance. In one experimental study, we compared spatial learning from real and virtual environments and from maps. In the second study, we examined alignment effects in virtual environments. In another study we compared the accuracy of different methodologies for collecting pointing estimates. In a fourth experiment we investigated how blindfold pointing is affected by path complexity. Lastly, we conducted experiments on the effects of image size (proximal and distal) on spatial learning and a study of learning from maps by scanning them sequentially.

PROGRESS

We tested over 220 participants in our major correlational study of spatial learning in real and simulated environments, a blindfold pointing task, self-report measure of spatial ability, traditional psychometric measures of spatial, verbal and reasoning ability and measures of spatial and verbal working memory capacity. We completed the coding of these data and made substantial progress on the analysis to reveal the factor structure of environmental spatial ability and how environmental spatial abilities are related to other psychometric and self-report measures.

The development of the Santa Barbara Sense of Direction Scale, a 15-item self-report measure of environmental spatial ability is complete. This scale has an internal reliability of .88 and a test-retest reliability of .91. This scale is being administered in all of our experimental and correlational studies and is proving to be quite predictive of performance in a range of environmental spatial tasks.

We completed a study of learning the layout of a building from a map, from direct experience, or by traversing through a "desktop" virtual rendition of the building. Participants in the virtual environment (VE) had the poorest performance, but their poor performance was limited to conditions in which they had to integrate information across different floors of the building. As expected, map learners formed an orientation-specific representation of the environment. VE learners also showed a preferred orientation, defined by their initial orientation in the environment. Learning a separate VE was highly predictive of learning a real environment, suggesting that similar cognitive mechanisms are involved in the two learning situations. A manuscript reporting this research was accepted for publication in *Memory & Cognition* (1999).

We carried out a literature review on spatial learning and orientation in VEs, focusing on the conditions under which alignment effects are found. This was presented at the Annual Meeting of the Association of American Geographers in Honolulu. We designed and collected data on a new study of alignment effects in VEs. We examined the contribution of three factors: the alignment of questions relative to the initial heading of the traveler, the global orientation of the entire path relative to the initial heading of the traveler, and whether direction estimates are made in situ or while imagining the locations.

In another series of experiments, we compared methodologies for collecting pointing estimates of direction (azimuth). Pointing was manipulated either with a manual pointer or by rotating the body to face a particular direction (a digital compass worn around the waist provided the direction scores in the latter case) and pointing was done either completely blindfolded or while wearing a vision-restricting hood, that allowed subjects to see the floor and pointer by their feet. Results indicate that pointing with a manual pointer lead to greater constant error (bias) in the data, whereas pointing by rotating the body lead to greater variable error. These and other results of this study, were written up in a manuscript and published in *Perception* (1999).

We have conducted two studies of individual differences in verbal navigation instructions. These studies showed that the quality of verbal navigation instructions could be assessed reliably by asking people to judge their quality. An extensive analysis of the instructions generated indicated that higher quality instructions are more complete, i.e. they mention more segments, turns and landmarks on the route to be described. Our correlational research on abilities related to production of verbal navigation instructions was presented at the Conference on Spatial Information Theory (COSIT) and published in the peer-reviewed conference proceedings.

We resumed work on our simulation program that generates routes made up of straight segments, and varying in certain parameters (i.e., turn sizes) while keeping others constant (i.e., number of turns). It produces both a visual record of the routes and records quantitative data in a file. The program is being used to characterize "route space", the universe of all possible routes with certain characteristics. We call the system ROCS, which stands for Route Complexity Simulator.

CONTRIBUTIONS TO BASIC SCIENCE

The project will increase our understanding of individual differences in environmental spatial abilities and their relation to other cognitive abilities. It will contribute to a broad theory of the psychology of space, distinguishing between spatial cognition at different scales of space, different levels of spatial complexity, and in both real and simulated environments.

POTENTIAL APPLICATIONS

This research has practical application in such contexts as personnel selection, education and training. For example our results to date suggest that both navigation in a desktop virtual environment and self-report sense of direction are highly predictive of navigation in real environments, suggesting that these might be good measures for use in personnel selection. By investigating navigation in both real and simulated environments, our research provides important information related to the use of simulated environments in personnel training.

The Preservation and the Decay of Military Skills

Contract #: N68171-95-C-9144
Institution: Ben-Gurion University of the
Negev, Israel Defense Forces

Contract Dates: 9/95-9/00
PIs: Avishai Henik, Esther Brainin & Varda
Ze'evi

SCIENTIFIC OBJECTIVES

One known fact of life is that people forget what they have learned. Forgetting depends on a variety of factors such as the quality of the skills required (e.g., types of knowledge), subjects' characteristics (e.g., age and expertise), and how long it has been since the learning. Much of the published literature on memory is based on laboratory research and short-term studies. The present research is a long-term field experiment that examines soldiers' memory while on reserve duty at various points in time (6, 12, 18 months) since release from mandatory military service. In particular, we study shooting skills of military tank gunners and missile operators (i.e., Dragon and Tow). This study investigates:

- 1) the rate of skill decay;
- 2) the impact of skill refreshment on the rate of skill decay;
- 3) the relationship between individual characteristics, such as memory or KABA (the IDF equivalent of the AFQT), and the retention of military skills;
- 4) forgetting of military skills ; and,
- 5) the relationship between declarative and procedural knowledge of the tested skills.

APPROACH

The study focuses on aiming and shooting skills of three weapons: Tow missiles, Dragon missiles, and tank main-guns. Soldiers are tested approximately three months before being discharged from the Army and at various points in time after their mandatory service. Shooting performance is tested with weapon simulators.

The chronological aspect of the study is delineated in the table below. The plus sign (+) indicates testing. The three weapon systems are tested according to the timetable below.

Testing period	Discharge	6 Months	12 Months	18 Months
Group A	+	*+		+
Group B	+		*+	+
Group C	+			+

For all groups, the difference in performance between the time of discharge and the first test constitutes an indication of change over time. In addition, the comparison of these performance differences across the three groups permits an assessment of change in performance as a function of elapsed time. The comparison of groups A and B with group C examines whether utilization of a simulator restores relevant knowledge, and to what extent. The comparison of groups A and B examines whether the timing of refreshing of skills using a simulator (after 6 or after 12 months - see "*" in the table above) affects performance.

Both practical (e.g., hit rate) and knowledge aspects of performance are measured at the testing points. In addition, various aspects of memory are tested at discharge. Memory tests include: verbal and visual free recall, paired associates, semantic memory, and memory for order.

PROGRESS

We tested a total of 338 subjects at discharge. The numbers of subjects that were tested at later points in time (e.g., 12 or 18 months) were smaller, between 10 and 30 subjects per group (A, B, or C), and weapon. Several subjects, who were tested in the first or second round of tests, were not available for testing after 18 months. We have not excluded them from the project yet, and hope to be able to test them in the future. This might enable us to look at performance after longer periods of time.

The current results show a decline in the hit rate for tank gunners and for the two missile systems. Accuracy in shooting also declines both for horizontal and vertical deviations from target locations, for tank gunners and for tow operators. The results of the knowledge tests are similar to the practical tests. The various memory tests are moderately correlated. Hence, it is quite possible that the various tests capture somewhat different aspects of memory.

CONTRIBUTIONS TO BASIC SCIENCE

This project will add to our knowledge of changes in memory for skilled performance over extended periods of time. Moreover, it will supply information regarding possible predictors of such changes. This will help us understand the possible mechanisms involved in the decline (or forgetting), with time, of skilled performance. In addition, we look at the possible relationships between individual memory characteristics and other individual abilities and changes in performance over time.

POTENTIAL APPLICATIONS

During the Gulf War, Wisher, Sabol, and Kern (1991) conducted a study of the Individual Ready Reserve. The findings of this investigation pointed to a significant reduction of military skills with time elapsed since the last period of training. Under certain situations there is a need to deploy armed forces on short notice, and possibly, with limited time and opportunity to practice military skills. Hence, it is important to develop efficient procedures for practice which include time parameters (e.g., how frequently should the tank gunner practice and for how long). These procedures and time parameters depend, among other things, upon the foreseeable decay of the given skill.

In this project we study the decay and preservation of military skills, in particular, the skills of missile launcher operators and of tank main-gun operators. We examine the rate at which these skills are lost and possible determinants of the rate of decay. Such research is valuable in enabling armed forces to cope with the problem and to demarcate policies for teaching and practicing military skills.

Using Latent Semantic Analysis and Construction-Integration Models to Assess Knowledge and Improve Instruction

Contract #: DASW01-98-K0004
Institution: University of Colorado

Contract dates: 7/01/98–6/30/01
PIs: Thomas K. Landauer & Walter Kintsch

SCIENTIFIC OBJECTIVES

The current project had two main objectives. The first objective was to design and test a prototype job and training classification system using Latent Semantic Analysis (LSA). This classification system could be used as a tool for matching available Army personnel with technical jobs and for identifying appropriate retraining materials for personnel whose jobs may have changed, evolved, or been eliminated. The second objective was to increase our understanding of LSA, as a tool for classification, and to extend its applicability to modeling the dynamics of verbal expression, within the training domain and in the wider domain of general human cognition.

APPROACH

The jobs of Army maintenance personnel can be characterized by the tasks and duties they perform. In turn, each of these tasks and duties is represented in the training manuals and texts used to learn the tasks and duties. Thus, each maintenance worker can be characterized by a set of texts- the manuals describing the jobs he or she is trained to perform. The same is true for new jobs, as they require the identification or development of appropriate training materials. LSA allows training texts to be described in terms of a set of descriptors (vectors) and for those descriptors to be related to each other. Thus, a training text can be characterized by both its descriptors and the relationships among those descriptors in multi-dimensional semantic space. For example, the tasks and duties as described in training texts for a helicopter maintenance worker would correspond to a set of semantic descriptors and the relationships among those descriptors. As tasks are created or evolved for a given job, they too can be added as new vectors in the existing multi-dimensional space that describes that job. The degree of differentiation, as represented by the cosine function between vectors, can be calculated as a measure of how similar or different any two (or more) vectors are in the semantic space.

When a new employee arrives or an existing worker needs to be retrained, their individual pattern of work experiences and skills can be identified and then compared to the semantic space models of a variety of jobs. Those individuals with the closest match to an existing job's requirements would be good candidates for placement or retraining for the identified job. Additionally, once a candidate has been selected for retraining, LSA can be used to identify appropriate training materials and to provide guidance on their sequencing.

PROGRESS

A total of 1529 Soldier's Manuals and Training Guides have been obtained and LSA models created for each of these training texts. These documents have been categorized into 14 top-level categories and into 8 to 12 subcategories according to their titles (e.g., all tank maintenance manuals form one category, with weapon systems, motor, etc., as subcategories). An index was created that allows quick identification of and access to the documents. A

supplemental program was written that randomly selected pairs of training manuals and then compared them using the LSA technique. This allows us to determine whether pairs of texts that LSA considers semantically close or distant are indeed close or distant in the original organizational scheme, and to detect relationships not represented in this scheme.

With the creation of this set of baseline Army Training Manual LSA-spaces, we have laid the foundation for the main objective of this project. The training manual spaces will allow the investigation of whether LSA can be used to select appropriate training documents for new personnel or those in need of retraining. The next step is to test the LSA spaces' ability to provide useful training and material recommendation for new or displaced personnel. Eventually, we should be able to select a small set of appropriate training texts that are optimized for retraining individuals so that they are able to perform a particular requested new task with minimum time and effort.

A longer-term objective is to provide content and criterion related validity evidence for the LSA described above by testing Army personnel in a variety of jobs and 1) making sure that the LSA spaces created by the training manuals are the same as those created by incumbents, and 2) provide evidence that the LSA created descriptors and relationships make consistent and useful training recommendations across jobs and tasks. Finally, it is hoped that the organization of the training documents identified by LSA will be a useful tool for the potential re-organization of training curricula along the categories identified by the analysis.

CONTRIBUTIONS TO BASIC SCIENCE

The work described above focused on two objectives: the exploration of a method for the production of summary texts using LSA, and the development of a model of predication as the foundation of an LSA-based science of word meanings. The main contribution relative to the first objective is the application of LSA to the development of sets of similarities and differences among training manual content. For example, the LSA procedure was applied to the text "Electrical and magnetic brain waves of two subjects were recorded for the purpose of recognizing which one of 12 sentences or seven words auditorily presented was processed." These are the first 5 obtained keywords: electroencephalogram, waves, magnetic, brain, sentences. The cosine between this list of words and the original text is .998, suggesting that the keywords derived by this process adequately capture the semantic content of the original text (a cosine of 1 indicates identity). The second objective, the prediction of required training texts, if confirmed, will allow for easier and more efficient assignment of training requirements, materials and will help in the placement of new and displaced personnel.

POTENTIAL APPLICATIONS

Once a prototype has been developed and tested, it could be used for the purpose of personnel selection in a wide range of domains. The major requirement for use in a novel domain would be the construction of an appropriate semantic space that adequately characterized the knowledge in that domain.

Informational Approach to Skill Transfer

Contract #: MDA903-93-K-0006
Institution: University of Illinois

Contract Dates: 8/21/93-8/20/97
PI: Gavan Lintern

SCIENTIFIC OBJECTIVES

The goal of this research was to expand knowledge about skill learning and transfer. The aim was to develop and test a theory of transfer with specific emphasis on visually supported flight skills.

APPROACH

Relatively little is known about the nature of fundamental skills underlying complex real-world tasks or how those skills are learned. The expertise of aircraft pilots was selected as a domain of suitable complexity and relevance. This research program was initiated with a review of the issues facing flight instruction. That review (Lintern, 1995) suggested several areas that were ripe for investigation, one of which related to the type of information used in piloting an aircraft and how pilots developed sensitivity to that information during flight instruction. The specific tasks of landing a light aircraft and of navigating an aircraft through an unfamiliar area were selected for intensive study.

The experimental projects undertaken in this program used a flight simulation system developed around a real-time computer-generated visual display. Two experimental paradigms were exploited. One was used to explore the visual information and skills used to support the aircraft landing task. As a means of identifying critical sources of information, experiments with experienced pilots examined how distortions in the simulated visual scene affected landing performance. The second paradigm evaluated transfer in a mission rehearsal task. A navigational database was developed and displayed via the visual simulation system. Flight students were taught navigational skills under different experimental conditions and were then tested in a realistic navigation condition.

PROGRESS

The landing work identified a number of the properties in a visual scene that pilots use for guidance and control of the aircraft (Doherty, 1996). The experimental work in this project has shown that there are a number of sources of information that can be used for guidance of a landing approach but that texture offers the richest and most readily usable source. Pilots function moderately well in the absence of texture, but the presence of texture enhances their accuracy and stability of control during the approach to landing. As further confirmation that texture has an important role, a mathematical analysis of texture gradients was used to establish that those gradients could, in principle, guide an approach to landing (Lintern, in press).

The Mission Rehearsal research has shown that interactive, real-time mission rehearsal is better preparation for a navigation task than the normal forms of preparation by map study (Bone & Lintern, 1999). In addition, it has shown that high workload during rehearsal can reduce the effectiveness of the method of preparation and that the richness of the visual environment has an effect on how useful mission rehearsal is for a visual navigation task (Gorton, in preparation).

CONTRIBUTIONS TO BASIC SCIENCE

This research program has made contributions in the areas of visual perception and skill transfer. While visual perception is one of the more heavily researched areas of the psychological sciences, there remains a dearth of knowledge about visual information used by operators of complex systems. There is essentially no complex control task for which there is an empirically demonstrated taxonomy of visual properties that support control behavior. This project demonstrated that some of the properties examined in basic visual science apply to the complex control task of landing an airplane.

Within the area of skill transfer, there is general agreement that transfer is based on similarities between training and transfer tasks. There is, however, no consensus on the nature of these similarities. An assumption underlying the project is that critical visual properties which support flight control constitute an important subset of those critical similarities. Thus, this work was aimed at identifying visual properties that support flight control and at examining some aspects of how they are implicated in transfer.

POTENTIAL APPLICATIONS

Many of the problems in learning to fly result from the difficulty of acquiring new perceptual skills and specific control strategies. The results of this work could enable the development of part-training strategies that will speed the acquisition of flight skills and that will guide the design and use of training simulators.

The research on mission rehearsal is the first to show that this method of familiarization can develop transferable skills. Mission rehearsal is a procedure that has received considerable publicity in recent years and is likely to be widely implemented within the US military. The research in this program engenders confidence that mission rehearsal will benefit operational performance. In addition, the research demonstrates some aspects of how a program of mission rehearsal can be evaluated.

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Working Memory Influences on Long-Term Memory and Comprehension

Contract #: DASW01-99-K-0001

Contract Dates: 06/15/99-06/14/02

Institution: University of Notre Dame

PI: Gabriel A. Radvansky

SCIENTIFIC OBJECTIVES

An important need of a large organization, such as the Army, is that complex sets of information about the world be readily understood by the people entrusted with that information. This would include the ability to understand descriptions of events occurring in some other part of the world or the need to understand and accurately remember instructions about how to perform (what to do) under various circumstances when the need arises. In order to understand information, a person must be able to successfully comprehend the nature of the events that are implied by the descriptions that have been provided. The retention of a collection of individual pieces of information is insufficient. A person must be able to properly relate the information to external circumstances in addition to retaining it. This project aims to assess how an individual's cognitive abilities can be used to predict their future performance on comprehension and long-term memory tasks. That is, this project aims to predict people's ability to understand the information they are presented with and then remember what that information was about later in time.

This project aims to investigate working memory influences on higher level comprehension, and the long-term memories that result from this comprehension (often called situation models because they are mental simulations of a set of circumstances that could exist in the world). Working memory is generally regarded as that portion of cognition where information is actively manipulated. The issue of interest to this project is the degree to which the successful processing of situation models can be predicted by traditional measures of cognitive ability, or are better predicted by measures aimed more directly at how these representations are created and retrieved. Previous studies have suggested that more traditional measures of working memory are inadequate for predicting situation model use. To address this, several studies are being conducted that look at various ability tests which can potentially be used to predict future performance in processing event and situation information. This is important because our knowledge about events in the world relies more on the situation models we create than on lower level representations, such as propositional codes. Situation models are a means of capturing and coordinating complex sets of information about circumstances and events.

APPROACH

This project is a series of experimental studies that examine individual differences in complex information understanding, as well as the subsequent memory for that information. The individual differences will be assessed using various individual difference measures of cognitive ability as well as looking at performance on various language comprehension and memory retrieval tasks that tap complex information processing about events and episodes. The cognitive ability measures are designed to quantify basic cognitive skills of a given person. In comparison, the performance measures are designed to assess the actual processing of complex sets of information, both during the actual process of understanding, as well as later remembering that information when it is needed. These performance measures cover a range of mental tasks including language comprehension, long-term memory, and logical reasoning. The data is

currently being collected both at the University of Notre Dame and Indiana University at South Bend to gain a relatively wider range of abilities.

PROGRESS

An initial study has been conducted that explored the accuracy of traditional measures of working memory abilities and their prediction of performance on various established situation model performance measures. We are currently analyzing this data. At this point it appears that more traditional measures of working memory are limited in terms of their ability to predict future performance, although they are predictive to some degree in some cases. Our new measure of complex event processing does a better job than these measures in certain cases, although there is room for further development. We are very optimistic that a battery of relatively quickly administered tests can be developed to address this issue.

CONTRIBUTIONS TO BASIC SCIENCE

The result of this project will be a greater understanding of working memory capacity and processes as well as the role they play in various aspects of comprehension and long-term memory that involve complex sets of information about the world. This follows and integrates a long tradition in each of these areas of cognition. Because the type of information that is of interest here is complex sets of descriptions about events in the world, how that information is processed, and how people can be identified that are either good or poor at this sort of processing makes this project appropriate for the U.S. Army.

POTENTIAL APPLICATIONS

The applications of this research for the Army are expected to be in the areas of training assessment and curriculum. If validated, an assessment battery measuring complex information comprehension and memory can be used to identify individuals who are better able to process this type of information, and potentially to identify areas of weakness in people that can be more directly improved upon.

Using Virtual Reality to Improve the Learning, Retention, and Application of Spatial Mental Models

Contract #: DASW01-96-K-0004
Institution: The Catholic University of
America

Contract Dates: 7/1/96 - 1/31/00
PI(s): Marc M. Sebrechts & Deborah M.
Clawson

SCIENTIFIC OBJECTIVES

Spatial mental models play a critical role in a wide variety of activities ranging from finding one's way through a city to developing a strategy for planning a hostage-rescue. Understanding the nature of these mental models and the power of virtual reality (VR) technology to augment our spatial skills is the central theoretical concern of this research. Within this broad framework we are interested in understanding how learning through VR affects spatial mental models and how those models influence the ability to retain and transfer information to the physical space.

APPROACH

We are following a two-pronged strategy in using virtual environments as a test-bed for assessing spatial skill. One approach focuses on developing medium-fidelity models of physical space and assessing the effectiveness of such models for training and transfer to the physical space. A second approach explores VR environments that have properties different from those in the real world.

In each of a series of studies we collected a variety of measures on learning, retention, and individual differences. The learning measure consists of determining the length of time to learn an architectural space. Retention is measured in several ways: response times for relative location judgments; accuracy of route following; identification of the location of obscured objects; drawing spaces from memory; recall of scene and object location. We also measured several characteristics of the individuals that may relate to performance on our spatial tasks, including visual memory, mental rotation, field dependence, spatial scanning, and associative memory.

PROGRESS

Two improved virtual environment models of campus buildings were completed. World Up Virtual Reality software was updated to enable stereoscopic viewing during exploration of the virtual environments on a large screen.

Additional data were collected on our series of studies on transfer of VR route training. Analyses indicated that results at a two-week delay were similar to those at immediate testing, reflecting a similar specificity of training. Performance after VR training was similar to that after real-world training, and was quicker and transferred better to navigating the real-world building than floor-plan training. However, this occurred only when the testing route was traveled in the trained direction. Individual differences in spatial scanning affected the success of transfer from VR to a comparable physical space. In another experiment, we assessed the role of field-of-view (FOV) in these data by comparing VR to real-world training using goggles that restricted FOV. Results indicated that restricted FOV accounted for some but not all of the VR training specificity.

Analyses were completed on two experiments assessing the effect of modifying the VR training to allow viewing of the entire space using transparent walls. VR training in the transparent-walled building led to substantially more accurate floor-plan drawings than VR training in the traditional opaque-walled building. Those trained with a transparent environment had a more Euclidean model of space; those using an opaque environment had a more typical city-block spatial model. A dissertation on this research was completed and defended.

Two new experiments on exploratory learning in VR were designed and conducted. Participants learned a space by exploring it rather than following a route. Analyses indicated that participants showed substantially better way-finding following VR training as compared with floor-plan training. In addition, VR-trained subjects showed greater precision in subsequent recall of object location.

Five conference presentations resulted from this work as well as a publication in a professional proceeding and a book chapter on "Transfer of Training in Virtual Environments".

CONTRIBUTIONS TO BASIC SCIENCE

Mental models developed from VR training reflect properties of the simulated environment. Learning a route in an opaque building leads to a mental model that maintains route distance, whereas learning a route in a transparent building leads to a mental model with both route and Euclidean distances. In addition, transparency enabled participants to quickly acquire survey knowledge about a structure that typically requires substantial time in the physical world. Despite multiple views in VR training, test performance depended on the relationship between route orientation during training and testing. This extends the types of spatial layout in which orientation specificity of mental representations has been demonstrated. Our results with exploratory VR are among the first demonstrations that virtual training may result in better way-finding than map-based training.

POTENTIAL APPLICATIONS

The results suggest that several alternative VR techniques may be viable in providing assistance for mission rehearsal, reconnaissance, and general navigation. Relatively simple spatial layouts can be learned quickly and effectively with this approach. In addition, training using transparent environments can lead to the acquisition of survey knowledge in a fraction of the time typically reported for real-world training. This may be especially important in other contexts, such as the development of situation awareness. In practical use, VR may lead to more attention to specific aspects of learning than is desired. At the same time, our preliminary results suggest that exploratory learning in VR may be better than map learning for planning optimal route traversal and for identifying specific locations of objects.

RACO RESEARCH OBJECTIVE #2:

***Provide fundamental knowledge to guide the development
and assessment of small team leaders.***

Research that falls under this heading is geared towards determining the effectiveness of team leadership as a function of leader behavior and team goals.

Development of Officer Leadership for the Future Army

Contract # DASW0199K0005

Institution: State University of New York at
Binghamton

Contract Dates: 9/15/99-2/29/04

PI Names: Bruce J. Avolio & Francis J.
Yammarino

SCIENTIFIC OBJECTIVES

The primary goal of this project is to evaluate, using two true field experiments, leadership models and methods that can accelerate the development of leadership among senior Army officers. Senior officers in an experimental training intervention are expected to be rated as more transformational by followers, peers, and superiors. Such leaders will also have a more positive impact on their followers' motivation and unit effectiveness and performance.

APPROACH

During the base period of this project, initial contacts were made with officers and staff in the Center for Army Leadership (CAL), the Command and General Staff College (CGSC), the Army Research Institute (ARI), and the University After Next (UAN) in the Center for Army Lessons Learned (CALL), at Fort Leavenworth Kansas. These contacts have initiated a broad range of discussions on how to best design and implement two true field experiments to test whether transformational leadership can be enhanced among senior Army officers. The two field experiments provide an opportunity to systematically evaluate whether transformational leadership can be developed and sustained over time with senior officer participants. Specifically, a sample of senior officers (yet to be identified), who are going through training will be randomly selected to participate in an alternative leadership development experience. The leadership workshop will be used to "create" leaders who are more transformational as compared with the traditional line of training.

Two cohorts of senior officers will be tracked over a two-year period to examine whether the impact of the experimental training intervention can be sustained over time. The experimental training will be customized, based on collaborations with instructors, to modify a foundation model of training, which has already been shown to have a significant impact on augmenting transformational leadership and unit performance with platoon commanders. The general components of the experimental training include a focus on developing the full potential of each officer using a well-validated model; providing assessment and 360 feedback to facilitate officers with their leadership development planning process; the use of other self development processes (e.g., feedback to boost the experimental training effects); and, support from peers and instructors both face-to-face and via web-based learning systems.

The actual training intervention will be comprised of a pre-assessment phase, followed by three contact days, and subsequent interactions with trainees spread out over twelve to twenty-four months. The initial contact days with officers will be followed by booster sessions that will be conducted via web-based learning systems developed for this experimental project. Criterion data will be collected at multiple levels of analysis over multiple time periods. These data will include what leaders' learned from the training and how they have applied what they have learned; personal development variables for both leaders and followers; 360 ratings of leadership style; unit cohesion, culture and readiness; and performance. We also intend to examine whether core attributes of effective leadership identified in the new Army leadership doctrine (FM22-100)

are being exhibited to a greater extent by officers who went through the experimental training intervention.

PROGRESS

During the base period of this grant, we met with Brigadier General Wood, to brief him on the scope of the project. Subsequent to that meeting, on November 6, 1999, General Wood, invited the two principle investigators on this project to brief staff at Fort Leavenworth on the scope of the project and the commitments that would be required from Fort Leavenworth. This briefing occurred on December 14 and 15, 1999 with the groups identified above. Subsequent to the briefings at Fort Leavenworth, we scheduled a follow-up visit to Fort Leavenworth to finalize plans for selecting the samples for the experiment, meet with relevant staff to operationally design the experimental intervention and layout the project requirements. During this period, we have also been reviewing materials for use in the experimental training intervention.

CONTRIBUTIONS TO BASIC SCIENCE

In the field of leadership, there are relatively few studies that have systematically examined whether any type of leadership can be developed and what the impact of enhanced leadership is on individual and unit performance. This project will test whether transformational leadership can be enhanced through a structured training intervention and whether we can sustain its impact on individual and group motivation and performance over time. For example, we will be able to examine whether inspirational leadership can be experimentally enhanced and have positive impact on follower morale, motivation, and unit cohesion.

POTENTIAL APPLICATIONS

All of the applications that will be tested and used to experimentally enhance leadership will be available for subsequent use for officer training. Specifically, the workshop materials and information technology on the web will be available for subsequent use in training, with a program that has shown demonstrated impact on learning, behavior, and results. Through the rigor of using two true field experiments, we will be able to determine more accurately which component processes in training have the greatest impact on enhancing leadership development over time.

Platoon Readiness as a Function of Transformational/Transactional Leadership, Squad Mores, and Platoon Cultures

Contract # DASW01-96-K-0008

Institution: State University of New York at
Binghamton

Contract Dates: 8/16/96-7/31/99

PI Names: Bernard M. Bass & Bruce J.
Avolio

SCIENTIFIC OBJECTIVES

The primary goal was to predict the leadership performance of platoons going through the Joint Readiness Training Center (JRTC). Transformational and transactional leadership theory is used as a basis for formulating predictions in the current investigation. It was expected that the performance of platoons would be higher if the leadership in the platoon was evaluated by multiple sources (superior, peer & subordinate) as being more transformational (charismatic).

APPROACH

360° evaluations using the Multi-factor Leadership Questionnaire (MLQ) of the platoon commander and sergeant were collected in garrison approximately one to two months prior to each platoon attending JRTC. Evaluations of the platoon's collective leadership profile and culture were also gathered in garrison from different rater sources in the platoon in order to reduce the effects of common source bias. Platoon commanders were rated by the CO, XO, CO-sgt, sgt, peers from two other platoons in their company and subordinates within the platoon, including squad leaders, fire team leaders, and squad members. Sergeants were rated by the CO, XO, CO-sgt, peers from two other platoons in their company and subordinates including squad leaders, fire team leaders, and squad members. Ratings of collective leadership and culture were based on the same dimensions/constructs contained in the MLQ, escalated to a group and company level of analysis. For example, measures were taken of the platoon's collective transformational leadership using the Team Multi-factor Leadership Questionnaire (TMLQ), as well as whether the platoon had a transformational culture using the Organizational Description Questionnaire (ODQ).

Performance in JRTC was evaluated by observer-controllers (OC's), who accompanied the platoons carrying out their assignments over a two-week period. A survey measure was developed to assess the platoon leader's (PL) performance, platoon sergeant's performance (PSG), their ability to work together in the field and the platoon's overall performance. A consulting team, who had extensive experience in the military, working in conjunction with the two PI's developed the criterion evaluation measure. OC rater input was also solicited in the development of the criterion measure. The criterion data collected at JRTC assessed the platoon's readiness and consistency of the platoon commanders' and sergeants' leadership with Army policy governing combat leaders. Ratings by the OC evaluators were collected at three points during JRTC, following the completion of each of three phases.

Modifications to all of the surveys were made following initial pilot data collection. Revisions were done in order to clarify items in both the predictor and criterion measures, and to drop items that did not contribute to the respective scales internal consistency.

Response rates for both the leadership and criterion measures have been consistently high at each of the data collection sites. Data have been collected for 90 platoons, 90 platoon leaders, and 90 platoon sergeants. Approximately 2700 respondents participated in this study.

PROGRESS

Data has now been collected on 72 platoons, which have gone through JRTC training, and 18 platoons that went through NTC. A total of 90 platoons and their company cadres (CO, XO, FSG) will have participated in this project at its completion. Analyses of survey instruments collected in garrison and at JRTC have been completed within each sample, as well as for the total sample (90 platoons). Using the MLQ and TMLQ surveys collected in garrison, exploratory factor analyses with the first data set collected have been conducted to identify the constructs underlying each of these survey instruments. As before for the MLQ, competitive models were tested for the TMLQ. Although a six-factor model of leadership was found to have the best fit for the data collected with the MLQ, a 5-factor model was optimal for the TMLQ. TMLQ produced a similar factor structure, except that Individualized Consideration and Contingent Reward loaded on a single factor, thus producing a 5-factor model.

Findings for the 72 platoons that have gone through JRTC indicated that the transformational leadership ratings of platoon commanders and sergeants collected in garrison did significantly predict the performance of the platoon mission effectiveness and effective platoon leadership at JRTC. Predictive validity varied by rater source. CO ratings of the MLQ factors in garrison of the PLs and PSGs were the most predictive of overall performance at JRTC. Self-ratings were the least predictive. PLs who were evaluated in garrison as more transformational, as using more contingent reward and less passive-avoidance led platoons with better performance at JRTC. A similar pattern was also found for the PSGs' leadership performance.

Exploring some of the qualitative data reported by OC's at JRTC confirmed the quality of the relationship exhibited between the PL and PSG was better in the most mission effective compared to the least mission effective platoons at JRTC. Systematic differences in cited strengths and weaknesses also emerged between the criterion groups.

CONTRIBUTIONS TO BASIC SCIENCE

Results to date support some of the basic propositions in transformational and transactional leadership theory. Specifically, we have been able to separate out at least 6 factors that represent the components of transformational and transactional leadership. Leaders exhibiting more transformational leadership not only received higher ratings of satisfaction and effectiveness in garrison, they also performed better as individuals and as an overall platoon at JRTC. Linkages of the quantitative results to patterns in the qualitative data collected at JRTC is offering some unique insights into what leaders do, as well as how frequently they do it.

POTENTIAL APPLICATIONS

The findings clearly support the utility of transformational and transactional leadership theory for use in military settings for predicting the readiness of units. Results indicated that selecting and developing leaders who are more proactive and transformational should show up in both how effective the platoon is in garrison, as well as under extreme conditions such as JRTC. Also, we have developed and evaluated military versions of the MLQ, TMLQ, and a reliable scorecard for use by observer-controllers at JRTC for assessing platoon readiness and PL/PSG leader behavior matching Army leadership doctrine.

Inter-Activity, Communication, and Trust: Challenges and Opportunities for Leadership in the Electronic Age

Contract #: DASW01-98-K-0009
Institution: University of Arizona

Contract Dates: 9/15/98-9/14/00
PI: Judee K. Burgoon, Suzanne Weisband,
& Josepha A. Bonito

SCIENTIFIC OBJECTIVES

The rapid, pervasive diffusion of new communication technologies, coupled with increased emphasis on distributed teams and teamwork, is fundamentally transforming the modern military. With these changes have come new challenges and opportunities for the exercise of leadership. Two related research programs are examining the effect of communication technologies on communication process and outcomes: leadership and team performance. Specific research questions being addressed by both research thrusts include:

- 1) What is meant by inter-activity? What structural properties of communication formats “afford” inter-activity and what interaction processes are experienced as interactive?
- 2) How do the affordances of inter-activity affect team member communication, social perceptions such as trust, and task performance? How can team trust be established or maintained when team members do not interact face-to-face (FtF)?
- 3) What essential properties of inter-activity need to be retained, simulated, or augmented when choosing a communication format or developing new behavioral technologies to maximize leadership and mitigate the effects of heavy task load?
- 4) What effect will initial FtF or mediated interaction have on subsequent team performance?
- 5) Can leaders be trained to motivate distant team members communicating electronically to perform their best, that is, to raise the team's collective efficacy so they feel confident that they can accomplish the task successfully?

APPROACH

In the Experimental Inter-activity Research Program, we are conducting five experiments to examine how various features of inter-activity that are intrinsic to communication and information systems (CISs) augment or attenuate exchange processes and resultant impacts on trust, other social judgments, and task-related outcomes. Experiment 1 tests the impact of user participation. Pairs of strangers collaborate on a decision-making task that is videotaped and subsequently viewed by observers so that observer perceptions and performance can be compared to participant perceptions and performance. Experiment 2 tests the effects of mediation and geographic proximity by comparing FtF participants to those who engage in proximal text-based interaction and those who engage in distributed text-based interaction. Experiment 3 tests effects of modality and information richness by comparing FtF interaction to text, audio, and audiovisual interaction. Experiment 4 has now become a longitudinal version of Experiment 3 so that it incorporates three different tasks (a social task, a case study decision-making task designed by Moberg, and the Desert Survival Problem) across two time periods. Experiment 5 examines effects of cognitive load.

In the Team Development Research Program, graduate and undergraduate students in two geographically distant U.S. universities participated in virtual team projects developed for their management information systems (MIS) classes. While the classes at the two universities

differed in a number of ways, the project was designed to simulate work in temporary virtual teams: (1) the project lasted 4 weeks; (2) vulnerability was high as the task was highly interdependent and required team interactions to achieve objectives; and (3) uncertainty was high as everyone was a stranger and all communications were to be conducted using some form of mediated communication. Teams were comprised of four members, where one of the members was a graduate student assigned as team leader.

PROGRESS

To date we have collected all data for Experiments 1, 2, and 3 and have partially completed Experiment 4. This semester, we will pre-test load manipulations for Experiment 5, complete data collection for Experiment 4, and collect Experiment 5 data. We are also currently revising and refining several of our conference presentations for publication, including submission to the National Communication Association. Experiments 2 and 3 are also being prepared for analysis. In addition, we have completed all data collection for the first round of the quasi-experimental fieldwork and are in the process of analysis and refinement. Two papers were submitted to two conferences.

CONTRIBUTIONS TO BASIC SCIENCE

Through the Inter-activity Research Program, we are gaining more insight into the processes by which people adapt to and interact through communication technologies. At the conceptual level, we have begun to refine what it means to be interactive and to develop a more comprehensive conceptual model of the structural affordances and the experiential process features associated with it. We have also expanded our conceptualization of the constituents of trust in work environments. Finally, we have proposed a causal model in which structural affordances lead to variability in communication process, which in turn affects social judgments, which lead to outcomes. In this model, rather than structural features of CISs directly affecting task outcomes, their impact is mediated by interaction processes and social judgments. At the empirical level, findings from our experiments to date, coupled with findings from concurrent research conducted in collaboration with human-computer interaction research at Umea University in Sweden, have supported the causal model.

The results from the Team Development Research Program, should have direct implications for current organizational theories that address distributed "virtual" processes for accomplishing work. As work becomes more global and distributed, the whole nature of organizing will inevitably be challenged and modified. Such changes need to be guided by systematic empirical work rather than by anecdote and personal experience, which in many quarters form the primary source of "data." The longitudinal fieldwork closely resembles the kinds of contexts faced by members of the same organization and members of teams assigned to projects with distant others.

POTENTIAL APPLICATIONS

Data from the Inter-activity Research Program, suggest that interface and communication technology designers should first establish the kinds of process and outcome goals that are important to their projects. Careful consideration of these issues will allow the design and selection of CISs that either increase the degree to which persons involved in distributed communication feel connected or similar or increase the likelihood of clear and direct

communication designed especially to influence. Studies that are in-progress or in the planning stage will provide more information regarding how interfaces accentuate or attenuate implicit communicative information, as well as demonstrate how such information affects process and outcomes.

The field research from the Team Development Research Program, will provide a unique opportunity to learn what it takes for distant teams and leaders to be successful by analyzing the actual interactions among virtual team members. It will reveal what communication practices are needed to create and sustain trust. A natural outgrowth of this work should be the development of training procedures for leaders in mediated settings. Other potential applications will be to develop software that will create a more visible form of social awareness for team members and leaders who cannot communicate face-to-face.

Information Management in Distributed Command and Control Organizations

Contract #: DASW01-95-C-0156
Institution: ALPHATECH, Inc.

Contract Dates: 9/30/95 - 12/31/00
PI: Eileen B. Entin

SCIENTIFIC OBJECTIVES

We define information management (IM) as the set of cognitive processes and behaviors that include the receiving, integrating, filtering, processing, seeking, and the exchanging of information. The major objectives of this project are to develop and test:

- 1) a cognition-based theory of IM applicable to information-rich, distributed command organizations;
- 2) a taxonomy of critical skills and knowledge requirements for producing effective IM processes;
- 3) a training program that enhances decision makers' ability to manage large amounts of information more efficiently and effectively; and
- 4) a training procedure that gives members of an organization deeper knowledge of the organizational structure, including each unit's goals, functions, and information needs.

A major premise of our work is that an effective IM training program can help people cope with the huge volumes of incoming information, increase the speed and quality of their understanding of the situation, and their decision making. A second premise, is that enhanced knowledge of the structure of their organization will make individuals more discerning about who needs information they have and from whom they can obtain critical information they need but do not have. The result will be a decreased in and out flow of unnecessary information.

APPROACH

The approach involves two component activities: modeling and experiments. A cognition-based model of IM was developed that provides a framework to link typical IM processes faced by a decision maker (e.g., filtering, fusing, transmitting), identifies errors observed in naturalistic settings, and suggests general approaches for remediation. It also identifies a subset of critical skills, behaviors, and knowledge bases that are most amenable to training. The model is being used as a hypothesis generation device for performance assessment and training experiments conducted in this project.

Experiments provide a complementary way of identifying requirements for a training program for managing information overload. They can be used to identify requirements for IM training, to investigate the impact of knowledge of organizational structure on IM, and to evaluate the training that is developed. The objective of our first experiment was to seek requirements for IM training. We conducted an experiment in which information handling under two levels of information load and two levels of organizational knowledge was assessed. As hypothesized, we found that subjects attained significantly higher situation assessment scores when information load was low than high. There was some evidence that deep organizational knowledge can enhance performance when information load is high. Subjects were not accurate in discriminating between critical and non-critical messages in either information load condition. In both conditions, subjects overrated the number of critical messages, suggesting that an important training requirement is to help people discriminate messages that are likely to be

critical from ones that are likely to be less important. Subjects were most accurate in the messages they directed to superiors and least accurate in the messages directed to subordinates, leading us to conclude that training in organizational members' roles, responsibilities, and information requirements would enhance IM.

PROGRESS

Integrating the model and the experimental results, we developed an IM training program designed to teach seven components of IM, conveyed by the acronym MISSION: mission delineation; identify critical elements of information, specify messages that could help you; speculate how you might help others; ignore irrelevant information; observe time constraints; and, narrow your focus. The training program includes lecture, demonstration, practice, and feedback components. We developed two forms of a booklet that described a joint organizational structure consistent with the scenarios used in the experiment program. One form (surface knowledge) provides a high level chart and brief description of each component's roles and responsibilities. The other form (deep knowledge) includes the high level chart, a more extensive description of each component's roles and responsibilities, and information about their information needs and the lines of communication among the components.

Thirty-six students at the West Point Academy participated in an experiment to assess the effectiveness of the training materials. There were three experimental conditions:

- No IM training and surface organizational structure
- IM Training only
- IM and organizational knowledge training

Prior to conducting the experiment, all subjects read a description of the scenario and the deep or surface version of the organizational knowledge booklet. Days 1 and 2 were devoted to IM training and training on the use of the simulator. The evaluation of the training was conducted on the third day. During a 30-minute time period subjects received approximately 80 e-mail-like messages from other components within the organization and from sources outside the organization, which they could read, reply to, and/or forward to another component. Subjects rated the criticality of each message they processed. Midway through the trial, they gave an oral briefing about the situation based on the messages they had processed. At the end of the trial, subjects completed a workload questionnaire, wrote a briefing, gave a final oral briefing, and responded to a questionnaire designed to assess their impressions of the training and supporting materials.

We are in the process of analyzing the data from this experiment. Initial analyses indicate that the subjects who received the IM training were more effective in identifying the critical messages than those who did not receive the training. We will use the findings from this experiment to increase the robustness of the training materials. The resulting training package will be evaluated in an experiment involving active-duty military officers.

CONTRIBUTIONS TO BASIC SCIENCE

This project enumerates a taxonomy of IM skills and provides a structural framework under which they are organized. It develops theoretically and empirically based principles and methods for training IM skills and knowledge in distributed decision making organizations. The development of a theory-based and empirically validated training program contributes an initial

step toward a science of distributed training. The work will also contribute to an understanding of the interactions between information flow and organizational structure.

POTENTIAL APPLICATIONS

The current problem of information overload is ubiquitous. The theory and training program can be applied in any organization that is subject to information overload, including military and commercial organizations. The application portions of the training program can be adjusted for any organizational content.

Identifying the Abilities Involved in the Acquisition of Tacit Knowledge

Contract #: DASW01-98-M-2036
Institution: Yale University

Contract Dates: 9/15/98–3/31/00
PI(s): Jennifer Hedlund & Robert J.
Sternberg

SCIENTIFIC OBJECTIVES

The primary objective of this one-year research project is to understand the processes underlying the acquisition of knowledge that is characterized as tacit. The term tacit knowledge is used by Sternberg and his colleagues (Sternberg, 1997; Sternberg, Wagner, Williams, & Horvath, 1995) to characterize knowledge that is acquired on one's own, procedural in nature, and instrumental to achieving one's personally valued goals. Tacit knowledge is viewed as one aspect of practical intelligence that distinguishes individuals who are more from those who are less successful. Individuals who are able to learn effectively from their experiences and apply their knowledge to the solution of real-world problems should have more success in dealing with the types of practical tasks they experience in their everyday lives.

In the present research, we focus our attention on the tacit knowledge that distinguishes military leaders who are more from those who are less effective. In our previous work, we identified examples of tacit knowledge in the stories and advice that leaders shared about their experiences, developed instruments for measuring the possession of tacit knowledge, and obtained evidence that tacit knowledge relates to effective leadership (Hedlund et al., 1998; Sternberg et al., 2000). The purpose of the present research is to understand why some leaders learn more effectively from their experiences than others. To address this issue, we seek to identify the cognitive processes that support the acquisition of tacit knowledge. Our efforts focus on three key knowledge-acquisition processes: selective encoding (the ability to extract relevant information from the situation), selective combination (the ability to integrate information into a meaningful interpretation of the situation), and selective comparison (the ability to relate new information to existing knowledge).

APPROACH

Our approach to understanding tacit-knowledge acquisition involves measuring the use of knowledge-acquisition processes in solving practical leadership problems. We present written descriptions of the types of situations encountered by leaders and ask participants to provide responses to those situations. The situations are drawn from the tacit-knowledge inventories developed in our previous work. The participants respond to the scenarios in one of two formats. The multiple-response format asks participants to rate the quality of several options for addressing each situation. This is the format used previously to measure tacit knowledge and provides a standard for comparing answers based on the new format. The new format is open-ended and asks participants to provide their own responses to each situation. This format represents a preliminary effort to identify the processes used by leaders in responding to the tacit-knowledge problems. We are examining leaders' responses to determine the extent to which they engage in selective encoding, selective combination, and selective comparison in the process of developing solutions to these problems. In subsequent efforts, we are seeking to assess more directly these processes by providing more detailed problem scenarios and specific question prompts following the scenarios. In the current research, responses to multiple-response format

questions are scored against an expert standard developed from previous research and responses to open-ended questions are examined using a coding scheme to isolate the three knowledge-acquisition processes. Scores on the multiple-response questions are used to distinguish leaders as high and low on tacit knowledge, and then their responses to the open-ended questions are examined further to identify the processes associated with tacit knowledge acquisition.

PROGRESS

We developed alternative forms of the Tacit Knowledge Inventories for Military Leaders (TKMLs) consisting of both multiple-response and open-ended questions. In Form A, all even-numbered questions are open-ended format and in Form B, all odd-numbered questions are open-ended format. In our subsequent work, under the contract "Understanding the Acquisition and Use of Tacit Knowledge," we are developing a small number of in-depth leadership scenarios in addition to these instruments, which will allow us to examine more thoroughly the tacit knowledge acquisition processes. We decided to limit this preliminary effort to the formats described above based on feedback from ARI and Army personnel and our interest in initially gathering unstructured responses to the tacit-knowledge scenarios. By limiting our instrument to the two formats described above, we were able to include more items and to administer the survey to a larger sample of military leaders.

We administered three versions of the survey, one for platoon leaders, one for company commanders, and one for battalion commanders to 64 leaders ranging in rank from lieutenant to lieutenant colonel. A subset of those respondents completed all three versions, allowing us to examine change in performance over leadership levels. We have scored the multiple-response questions and are in the process of coding the open-ended responses. We also successfully administered electronic versions of the instruments, using both the Internet and desktop computers. We are in the process of revising the on-line version to facilitate data collection and scoring, which will allow immediate feedback to be provided to participants.

CONTRIBUTIONS TO BASIC SCIENCE

Our research addresses the basic question of how people acquire tacit knowledge. In previous research we have shown that tacit knowledge is relevant to successful performance in a number of domains, including business management, education, and most recently military leadership (Hedlund et al., 1998; Sternberg et al., 1995). So far, these efforts have focused on measuring existing knowledge, not necessarily the ability to acquire tacit knowledge. Furthermore, they have focused more on establishing the relationship of tacit knowledge to performance than on identifying ways to develop such knowledge. By measuring how leaders interpret and respond to realistic leadership situations, we hope to obtain preliminary insight into the processes that are associated with the effective acquisition of tacit knowledge. We expect that these processes will be generalizable to other performance domains.

POTENTIAL APPLICATIONS

The findings of this research have potential implications for both the measurement and development of tacit knowledge. In terms of measurement, we are exploring an alternative approach to assessing tacit knowledge that requires leaders to express in their own words a solution to the problem, which may serve as a more direct measure of their tacit knowledge than asking them to evaluate the quality of solutions provided. We also have obtained a set of

additional responses, adding to the abundance of data we have for the existing tacit-knowledge scenarios, and which can be used as a source for assessment and development tools. We will have potentially identified the key processes associated with tacit-knowledge acquisition, which can be used to develop instruments to measure leadership potential or as the foundation around which leadership development activities are designed to promote more effective learning from experience.

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Understanding the Acquisition and Use of Tacit Knowledge

Contract #: DASW01-99-K-0004
Institution: Yale University

Contract Dates: 8/15/99–8/14/00
PI(s): Jennifer Hedlund & Robert J.
Sternberg

SCIENTIFIC OBJECTIVES

The objectives of this research are (a) to understand how leaders acquire experience-based practical knowledge and (b) to explore how tacit knowledge fits into a greater understanding of effective leadership performance. *Tacit knowledge* characterizes knowledge that is practically oriented, personally relevant, and acquired with little environmental support (Sternberg, 1997; Sternberg, Wagner, Williams, & Horvath, 1995). Tacit knowledge is viewed as an aspect of practical intelligence that distinguishes individuals who are more from those who are less successful. Individuals who are able to learn effectively from their experiences and apply their knowledge to the solution of real-world problems should have more success in dealing with the types of practical tasks they experience in their everyday lives.

In previous work, we developed instruments to measure the tacit knowledge of military leaders and obtained evidence that tacit knowledge relates to effective leadership (Hedlund et al., 1998; Sternberg et al., 2000). Our current efforts are aimed at identifying the cognitive processes associated with tacit-knowledge acquisition. In other words, we seek to understand why some leaders learn more effectively from their experiences than others. The purpose of the present study is to develop instruments to assess these processes and to establish the relationship of these processes to other indicators of leadership effectiveness.

APPROACH

Our approach to understanding tacit-knowledge acquisition involves measuring the use of knowledge-acquisition processes in solving practical leadership problems. We intend to use detailed problem scenarios to assess these processes. The scenarios present leadership situations that are representative of those likely to be encountered by officers while on the job. The scenario ideas are drawn from a set of leadership stories compiled as part of previous tacit-knowledge research and, therefore, reflect situations from which leaders previously have acquired tacit knowledge. Each scenario is accompanied by supporting documents such as memos, personnel files, reporting procedures, and activity logs, which pertain to the situation. This information, however, varies in its relevance to addressing the situation. The respondent is asked to read through the materials presented and to answer specific questions designed to assess the extent to which leaders invoke certain executive processes in the process of solving problems, processes that contribute to knowledge acquisition. These processes include problem identification, information processing (e.g., selective encoding, selective combination, and selective comparison), solution generation, and outcome monitoring. For example, "What do you see as the main problem in this situation?" assesses problem recognition and definition; and "What information did you use to formulate your strategy for addressing the problem?" assesses selective encoding. Responses to the scenario questions will be rated on the various knowledge acquisition processes. Scores on these scenarios will be evaluated within a broader framework of leadership effectiveness measures, which will include measures of tacit knowledge for military

leadership, formal job knowledge, general cognitive ability, and leadership effectiveness. We plan to test the relationship among these measures at two levels of leadership: platoon and company.

PROGRESS

We collected pilot data, under the previous contract "Identifying the Abilities Involved in the Acquisition of Tacit Knowledge," in which respondents were asked to provide their own solutions to abbreviated tacit-knowledge scenarios. Initial analyses indicate that leaders do vary, to some extent, in their problem identification and use of information. The responses based on the abbreviated scenarios, however, are limited in their length and detail, suggesting that more in-depth scenarios and directive questions should provide a better assessment of tacit-knowledge acquisition processes.

We identified a set of six problem situations from the pool of items collected during previous tacit-knowledge work from which to develop detailed problem descriptions. We compiled various military resources (e.g., training manuals, leadership handbooks) to assist in developing supporting documents (e.g., letters, training schedules) and background information for those scenarios. In developing the scenarios, we are striving to provide enough detail in order to assess adequately the knowledge acquisition processes, while avoiding excessive technical information that might unfairly favor those with more military experience. We currently are revising draft items of the scenarios and plan to submit them for review by military practitioners within the next two months.

CONTRIBUTIONS TO BASIC SCIENCE

In our research, we are exploring the question of how leaders acquire tacit knowledge. Previous efforts focused on measuring acquired knowledge and assessing its relationship to performance (Hedlund et al., 1998). Current efforts are aimed at identifying the potential to acquire tacit knowledge and ways to develop such knowledge. We expect to show that certain cognitive processes are associated with more effective acquisition of tacit knowledge and that these processes are also related to more effective leadership. Through developing a measure of these knowledge acquisition processes, we may provide an alternative method of assessing leadership potential. Further, these processes are expected to underlie successful performance in other domains where learning from experience is critical.

POTENTIAL APPLICATIONS

The findings of this research have potential implications for both the measurement and development of tacit knowledge. In terms of measurement, we are developing an instrument that will assess knowledge-acquisition skills, and thus the potential to learn from one's experiences. Such a measure may provide a tool for evaluating one's own learning processes and for developing one's knowledge-acquisition skills. The scenario materials also may stimulate new thinking about leadership and provide additional lessons beyond those gained from reading doctrine or training materials. If we establish that the cognitive processes measured by our instrument are related to the acquisition of tacit knowledge and performance, we have identified a means for improving performance through the development and use of more effective knowledge-acquisition processes. That is, leaders can be given instruction on the specific

processes that are useful for learning from experience and they can be given opportunities to practice using these skills.

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Knowledge-Driven Decision-Making - A Pilot Study

Contract #: MIPR8MDSG98050
Institution: University of Haifa

Contract Dates: 9/25/98-10/10/99
PI: Raanan Lipshitz

SCIENTIFIC OBJECTIVES

This was a pilot study for a multi-year project with four objectives: (a) to develop a model of knowledge-driven decision-making; (b) to study the development of proficient complex decision-making; (c) to develop a methodology for improving decision-making skills; and (d) to tackle the dilemma of rigor vs. relevance in the study of decision-making. The objectives of the pilot study are to design and test operationalizations for mental models and decision strategies in the micro-world (computer driven behavioral simulation) that will be used in the multi-year project, Gettysburg!.

APPROACH

Through the course of the study, we ran several subjects, testing different Gettysburg! scenarios, data collection and analysis methods, in order to (a) identify a set of scenarios with progressively increasing difficulty levels; (b) devise a method for teaching subjects the technical aspects of the game "buttonology" within a reasonable time period; and (c) design methods for collecting data on subjects' planning, mental models of the situation, information search and decision strategies, and criteria for assessing performance quality.

PROGRESS

The project is completed, producing a research program with two objectives: (a) studying how people skillful performers on complex decision making tasks and (b) exploring how this process of skill acquisition can be expedited by means of effective training.

CONTRIBUTIONS TO BASIC SCIENCE

Through the within-subject longitudinal study of the development of expertise in complex decision making covering the full range novice to expert skill levels, this research could potentially provide useful information and insights on the development of expertise and on novice and expert differences. In addition, this research could contribute information on skill acquisition at the sparsely studied upper end of the skill level continuum, making it particularly useful for the study of training.

The current research provides a rigorous test of NDM's expert-based approach to prescription whereby abstract analytical models are replaced by experts performance as normative yardsticks. Through investigation of what lessons players draw from experience and how they implement those lessons, the program takes first steps at exploring Klein's intriguing suggestion that "instead of teaching people how to *think* like experts, we can try to teach them how to *learn* like experts."

Lastly, the research contributes to narrowing the dilemma of rigor vs. relevance that confronts students of decision making by applying microworlds methodology to the study of decision making. This methodology permits rigorous observation of decision processes that approximate real-world decision-making Lipshitz (1997).

POTENTIAL APPLICATIONS.

The findings of this research will have potential applications in the development of a new reflective training methodology that is specifically geared to different skill levels.

Testing Schneider's ASA Theory

Contract #: DASW01-96-K-0003
Institution: University of Maryland at
College Park

Contract Dates: 4/30/96-9/30/99
PI: Benjamin Schneider

SCIENTIFIC OBJECTIVES

The purpose of this contract is to test the hypothesis of homogeneity of personality of leaders, statistical modeling of this homogeneity, the relationships between leader personality and individual and organizational outcomes, and the role of the individual leader's personality in the behavior of the organization, as predicted by Schneider's attraction, selection, and attrition (ASA) theory of leaders in organizations. ASA theory proposes that over time, specific leader personalities come to define organizational settings as an outcome of the ASA process.

APPROACH

The scientific approach to work on the project has involved extensive data collection on leader personality and also leader life history experiences and the use of those data for predicting the organizations in which the leaders work. In addition, some research has also been conducted on adolescent leaders to explore the early development and predictability of future adult leaders. Finally, considerable conceptual progress has been made in identifying additional issues to understand the impact of leader personality on organizations.

PROGRESS

Since the contract began there have been several published studies by Schneider and others that lend support to his fundamental hypothesis that homogeneity of personality of leaders in organizations is to be expected. Two studies of homogeneity have been carried out under the contract. The first studied a sample of 12,000 leaders from 142 American business organizations. These leaders had attended leadership training at the Center for Creative Leadership (CCL) in Greensboro, NC; each had completed the Myers-Briggs Type Indicator (MBTI). Schneider showed that a statistical model he developed based on the MBTI data could be used to significantly predict (a) the industry in which the leader worked and (b) the company for which the leader worked. In the second study, he showed that the life history experiences of attorneys and accountants could be used to develop a statistical model for assigning (a) accountants to one of the four accounting firms for which the accountants worked and (b) attorneys to one of two law organizations for which they worked.

Simultaneous with this work on leaders already in business, Schneider became interested in leadership among adolescents and the long-term predictability of (a) leadership for these adolescents and (b) the predictability of the kinds of settings in which they might eventually choose to work. He has shown that both adolescent personality and adolescent career orientations and interests predict teacher and peer ratings of leadership over time (18 months to date) and that these predictions differ from predictions of adolescent peer ratings of popularity and friendship.

These projects have resulted in a number of conceptual papers on the ways by which leader personalities and interests come to define organizations and the behavior of those organizations. Two themes have emerged in this conceptual work. One theme concerns the role

of the individual leader's personality in the behavior of the organization; this stands in contrast to most writings on organizational behavior that attribute such behavior to structure and strategy. A second theme concerns explicit specification of the cross-level issues involved in exploring relationships between leader personality and individual and organizational outcomes.

CONTRIBUTION TO BASIC SCIENCE

With the exception of personnel selection researchers, organizational science has been dominated by a situationist perspective. This perspective implicitly and, in many cases, explicitly argues that organizations are what they are as a function of the jobs in the organization, the structure of the organization, the predominance of teams in the organization, the technology that characterizes the organization, and so forth. ASA theory takes a different tack, proposing that organizations are what they are due to the people in them. To test this idea, it must first be shown that organizations tend towards homogeneity and the two studies we have conducted to date lend some support to this hypothesis. From a fundamental science standpoint, these findings offer alternative explanations for organizational behavior. That is, the findings indicate that it may be that, at root, organizations take form as a function of the people in them rather than the more tangible or surface issues on which organizational scientists have previously focused.

POTENTIAL APPLICATIONS

The results to date suggest several potential applications, one regarding personnel selection and the other with regard to organizational change efforts. When harmony, cooperation, and morale are key outcomes of interest, ASA theory suggests that people who are similar to those already in the organization should be hired. This conclusion suggests the inclusion of issues related to hiring for the organization, not just the job, in personnel selection. ASA theory also suggests that, when organizational change is required, simple realignment or restructuring may not achieve the intended goals because the same people will still be in the organization; if people are the root of what an organization is then it is the people who require changing, not the structure of the organization.

Finally, the research on adolescent leadership may have important implications for the Army because of its focus on young adults and because of the focus on peer ratings of leadership. The finding that leadership is predictable may be of value in creating instruments to aid in the selection of soldiers for appropriate leadership assignments. These leadership selection instruments may also be used to help determine which soldiers are most likely to benefit from further leadership training.

Distant Leadership Under Stress

Contract #: DASW01-99-K-0003
Institution: University of Maryland,
Baltimore

Contract Dates: 08/01/99-07/31/02
PI: Yan Xiao & Colin Mackenzie

SCIENTIFIC OBJECTIVES

The overall objective of this project is to investigate leadership effectiveness when leaders are at a distance from the team. Since the role of leadership in team performance can hardly be overstated, understanding how leadership impacts on team performance is important to military as well as to civilian organizations. With widespread use of electronic communication technologies, it has become essential to establish a theoretical and empirical basis for predicting how new communication technologies may impact on leadership and team performance.

To achieve a better understanding of distant leadership under stress, this research program involves two intertwining lines of efforts. One is to develop a conceptual model of the interaction between task structure, stress, communication modality, and leadership effectiveness; the other is to conduct an empirical study of distant leadership using a real, dynamic, and stressful work environment as a laboratory. The specific objectives of the research program are: (a) developing a matrix of leadership function and of situations in which leadership functions are needed; (b) developing a leadership model, which prescribes nominal processes through which a leader applies control over and influence on team activities, either co-located or at a distance; (c) developing leadership measures applicable to leadership in a dynamic, team environment; and, (d) conducting a series of prospective studies in a real event-driven stressful environment to evaluate the impact of various communication modalities on leadership, using the measures developed.

APPROACH

The theoretic and conceptual efforts (specific objectives a-c) will be based on existing literature on team performance and on analysis of an existing video library of team performance collected in a stressful environment. The cases from the video library will be reviewed to extract segments representative of effective and ineffective occurrences of leadership. These segments will be used as basis for the leadership matrix, model, and measures. Prospective empirical efforts (specific objective d) will utilize an already established study environment in a Level-I trauma center. Comprehensive audio-video recordings will be the primary data collection method. Three modes of communication will be randomly assigned in consecutive cases. Leadership effectiveness will be measured by both team performance (speed and accuracy) and process parameters (decision processes and leadership control processes). These dependent variables will be analyzed in relationship with independent variables including risk, urgency, uncertainty, task structure, and workload.

PROGRESS

We are currently working on the theoretical formulation of leadership functions in team settings. In addition to reviewing relevant literature, we have selected and reviewed videotaped real-life team performance to understand the range of leadership behaviors in intense, highly stressful circumstances. We have also successfully constituted a group of core study participants

and subject matter experts for the purpose of coordinating future prospective studies and data collection. We plan to develop a draft version of leadership function matrix in the next two months and finish the first round of reviewing of videotapes. In connection with these efforts, we will work with our collaborators to develop leadership measures suitable for the planned prospective studies on distant leadership.

CONTRIBUTIONS TO BASIC SCIENCE

Our proposed studies have several unique features compared to previous attempts to study leadership. Firstly, we will focus on performance-based measurement of leadership effectiveness in a highly dynamic team environment. Secondly, empirical data will be from a real environment. Thirdly, our study environment allow direct observations and audio-video recordings of real team activities under stressful situations and manipulation of communication modalities between leaders and team members.

POTENTIAL APPLICATIONS

We anticipate that our efforts will fill a current void in understanding leadership processes in the context of team performance and provide a basis for future training programs and other interventions to enhance team performance, especially when leaders and members are separated by distance.

Leadership, Team Cognition, and Team Performance: The Development and Influence of Leader Mental Models on Team Mental Models and Team Performance Regulation

Contract #: DASW01-96-K-0002
Institution: George Mason University

Contract Dates: 4/25/96-9/30/99
PIs: Stephen J. Zaccaro & Richard Klimoski

SCIENTIFIC OBJECTIVES

Leadership and team performance are critical elements of military effectiveness. Yet, despite vast literature on leadership and team dynamics, respectively, there is surprisingly little conceptual research on precisely how leaders create and direct team processes to achieve collective success. Two fairly recent developments in both leadership and team performance research have provided a basis for developing a conceptual framework that specifies the critical components of effective *leader-team* performance. One is a perspective that defines leadership as discretionary problem solving directed toward the facilitation of team and organizational goal attainment (Fleishman, Mumford, Zaccaro, Levin, Korotkin, & Hein, 1991; Hackman & Walton, 1986; Mumford, Zaccaro, Harding, Fleishman, & Reiter-Palmon, 1993; Zaccaro et al., 1995; Zaccaro, et al., 1997). Such problem solving involves the development of mental models that facilitate a leader's understanding of different problem domains, the subsequent derivation of effective solutions, and the leader's interactions with their team. A second development is the increasing application of cognitive theories and models to team performance. For example, Cannon-Bowers and her colleagues have argued that effective team coordination and performance depends upon the emergence of accurate *shared mental models* of requisite team strategies and interaction tactics among team members (Cannon-Bowers & Salas, 1990; Cannon-Bowers, Salas, & Converse, 1993).

Based on these developments, the scientific objectives of the present effort were to measure, examine and describe the influence of leader mental models and leader communications on the development of team mental models and subsequently, on team coordination and performance. These influences were to be explored in both laboratory and field settings. Also, because there is a lack of conceptual perspectives integrating both leadership and team dynamics, another objective of this research effort was to convene a conference of scholars who have completed research in either or both of these domains. The intent of this conference was to explore and discover different perspectives on leader-team performance.

APPROACH

This research effort was composed of both experimental and field studies, as well as the conference. Two experimental studies were used to investigate how leader communications influence the emergence of team mental models. In the first study, we manipulated the quality of team training and the content of leader briefings and observed the effects on emergent team mental models, team processes and team performance. In the second study, we examined how leader sensemaking processes were related to the quality of team mental models and team adaptation. Sensemaking processes include extracting important environmental cues, placing these cues in a team's performance context, and embellishing the meaning of these cues into a coherent framework. This framework provides team members an enriched mental model of cue-response contingencies, linked to environmental events, and includes the meaning or rationale for

why certain collective actions are more or less appropriate in different situations. It is this last feature of sensemaking that produces shared mental models promoting team adaptation in a dynamic environment. In this study, we manipulated the content of a leader's communication with a team to reflect one of these four levels of sensemaking.

Two field studies were designed to examine team mental models in hierarchical Army teams in training settings. A major task in this effort was the construction of measures to assess leader and team mental models in natural settings. In the first field study, completed with an Army command and control team, overlapping case studies were used to illustrate how team processes enabled two different types of teams to adapt, with varying levels of success, to changes in their performance environments. The second field study was designed to develop and validate a measure of shared mental models to be used in the context of a Virtual Training Program (VTP). Such a measure, constructed to capture some of the key psychological processes linked to the effective performance of tank platoons, would provide a vehicle for assessing the efficacy of possible instructional design changes. It can also be used to specify where units who participate in the VTP need more targeted training as they develop the knowledge and skills necessary for successful field exercises and live combat. Soldiers who were either experts or novices in the context of the VTP training exercise completed the prototype measure.

The conference was designed to facilitate discussions among leadership and team scholars around specific themes related to the team interface. The conference format included four speakers: Richard Klimoski, Richard Moreland, Fran Yammarino, and Paul Goodman. It also included 7 working groups that considered several themes related to the influence of integrated leader/team processes on work effectiveness.

PROGRESS

The data from both laboratory and field studies have been collected. Results from the first study indicated that both team interaction training and enhanced leader briefings prepared teams to confront both routine and novel environments by developing accurate and similar knowledge structures. The training and briefings also influenced the flexibility of member mental models, such that effective teams were able to adjust their mental models accurately before embarking on new performance environments. Qualitatively different mental models were required in each new environment, and both the enhanced leader briefing and the team training interventions yielded significant main effects on mental model accuracy. Thus, we concluded that the information contained in the manipulations enabled the participants to readily adapt their mental models as circumstances warranted. Teams *without* enhanced leader briefings or interaction training were not as able to adjust their mental models as accurately or in a coordinated fashion when confronted with novel circumstances. These findings point to the importance of leadership influences on team mental models, and by extension, team adaptation.

Data from the second study indicated that leader sensemaking significantly influenced both team mental model accuracy and similarity, with elaborated sensemaking resulting in more accurate and shared models. More importantly, the quality of a leader's sensemaking communications had a significant effect on team adaptation, and this effect was fully mediated by the influence of sensemaking on team mental models. Only those teams that received information about their environment within a meaningful structure were able to maintain their level of performance in the face of novel environmental conditions. These teams also had

significantly more accurate mental models. In all other conditions of leader sensemaking, team performance declined precipitously in the novel environment.

In the first field study it was found that certain key team processes (e.g., mission analysis, situational awareness, communication, decision-making, adaptability; see Prince, Brannick, Prince & Salas, 1992) were associated with team effectiveness. We also found that effectiveness relied heavily on the extent to which teams could adapt to changing circumstances in their performance environments. While, undoubtedly, better staffed and trained teams are likely to be more successful than less fully prepared ones, the ability of teams to mobilize and coordinate their efforts also played a large role. Accordingly, team-training interventions are likely to play critical roles in the facilitating the effectiveness of military units. As evidenced in the two teams that we observed, such processes are likely to be particularly important when teams face dynamic environments and rely on complex technology. The results from the second field study confirmed that this measure reflected the METT-T decision model that is the basis for training Army tank platoons, verifying its usability and validity.

An outcome of the conference that was conducted on September 26-28, 1997 is a special issue of *Group and Organization Management*, titled, appropriately, "The Interface of Leadership and Team Processes in Work Organizations."

CONTRIBUTIONS TO BASIC SCIENCE

One product of this effort has been a conceptual framework that integrates leadership and team processes to explain effective collective performance. Such frameworks are not common in either the team or leadership literature. Also, the laboratory studies have contributed information about how leader communication and sensemaking influence the content and structure of team mental models. Finally, the special issue that is a by-product of the conference is expected to provide some insights into the key elements of leader-team interactions.

POTENTIAL APPLICATIONS

The applications of this research for the Army are expected to be in the areas of training assessment and curriculum. The measures of individual and team mental models that were developed, can serve as effective training assessment tools. Such tools can indicate where team members are weak in their understanding of requisite team processes and provide the basis for remedial interventions by trainers. The findings regarding the role of certain leadership processes that contribute to effective team performance can contribute to the development of curricula for use in early leader training programs.

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Leadership, Team Processes, and Team Adaptation: The Development and Influence of Functional Leadership Capabilities of Team Adaptability to Adversity

Contract #: DASW01-98-K-0005
Institution: George Mason University

Contract Dates: 8/1/98-7/31/01
PIs: Stephen J. Zaccaro & Richard Klimoski

SCIENTIFIC OBJECTIVES

Leadership and team performance are critical elements of military effectiveness. Yet, despite vast literature on leadership and team dynamics, respectively, there is surprisingly little conceptual research on precisely how leaders create and direct team processes to achieve collective success. In particular, there has been little consideration in both the team and leadership literature given to (a) the team cognitive, motivational, and coordination processes that specifically promote team adaptation; (b) how leaders influence the quality of these processes; (c) the personal qualities of the leader and of team members that promote team adaptation; and (d) leader and team training principles that specifically foster team adaptation.

The purposes of the proposed research program are (a) to examine in more detail the influences leaders have on team processes contributing to team adaptation, (b) to examine training and development principles that contribute to the development of adaptive military leaders and teams; and (c) to develop and examine the psychometric properties of a leader assessment tool that measures personal qualities contributing to adaptation. We are meeting these objectives with a series of experimental and field studies in which we examine leadership and the motivational, cognitive, and coordination processes that contribute to team adaptation. We also intend to examine and validate integrated leader and team development guidelines that would foster these processes. Finally, our research efforts will also yield assessment tools designed to measure the influence of leader characteristics on leadership and team adaptability.

APPROACH

This research effort is composed of both experimental and field studies. The experimental studies are intended to examine (a) leader attributes that promote leader and team adaptation, and (b) training feedback characteristics that foster team adaptation. The field studies are designed to (a) validate an assessment battery constructed to measure multiple attributes related to leader flexibility, (b) examine work experiences related to the development and emergence of attributes promoting leader flexibility, and (c) test training principles regarding the development of leader flexibility. We are planning to use the Army War College (AWC) as a site for these field studies.

PROGRESS

We have developed the testbed for the experimental studies and are completing our first study. Specifically, we have selected a new battle simulation that is more advanced from the one used in previous research funded by ARI. After installing this simulation, we conducted cognitive and behavioral task analyses for the purpose of developing appropriate measures of individual and team mental models. We are currently collecting data to assess the effects of process versus outcome feedback, and individual versus team-level feedback on team adaptation. We are also examining the role of certain leader adaptability attributes on team processes and performance.

For the field research, we have conceptual models that describe influences of work experiences, formal instruction, mentoring and coaching processes, feedback systems, and self-development experiences on individual attributes related to leader flexibility. We have also developed an assessment battery that measures cognitive, behavioral, and dispositional attributes linked to leader flexibility. We have completed several validation studies, affirming the psychometric strengths of this battery. We are currently developing criteria that can be used to validate these measures and conduct further studies with AWC students.

We have also examined archival sources of work experience data in order to relate specific categories of work experiences to the development of key leader adaptability attributes. We are using these data to construct a qualitative instrument to assess officer work experiences.

Finally, we have developed a proposal for a training program to be implemented at the AWC. This program applies principles of adaptability training that were derived from the conceptual models developed in year one of this effort. We are currently implementing a shortened version of this program at AWC as part of a class on creativity and leadership.

CONTRIBUTIONS TO BASIC SCIENCE

One product of this effort is a comprehensive conceptual framework that describes a career-long process of leader development. This framework builds on previous research in the literature and incorporates multiple sources of developmental experiences (i.e., formal training, self-development, work assignments, mentoring, coaching, feedback). Accordingly, it is particularly appropriate for the U.S. Army. Also, the data from the planned laboratory and field studies should validate training principles regarding the efficacy of particular kinds of interventions designed to grow adaptability skills. These data should also provide information regarding the development and influences of leader and team attributes that promote adaptability.

POTENTIAL APPLICATIONS

The applications of this research for the Army are expected to be in the areas of training assessment and curriculum. If validated, the assessment battery measuring leader flexibility can serve as a very effective training tool in multiple Army training settings. Further, the field studies are expected to yield specific guidelines and curriculum tools that target the development of leader flexibility. These guidelines and tools are expected to be constructed in accordance with the different developmental needs that emerge at various points in an officer's career. Also, the adaptability training program being implemented at AWC should have direct applicability to the development of adaptive senior leaders.

RACO RESEARCH OBJECTIVE #3:

As the Army evolves from a Cold War force to the 21st century, understand and anticipate the impact of societal trends and changes in the Army and its missions on soldiers.

Research in this section describes and analyzes the effects of peacekeeping operations on soldiers, their families, and the Army. In addition, this research determines the effects of military involvement on the well-being and societal functioning of soldiers and their families.

Leadership for Change

Contract #: N68171-98-M-5540
Institution: University of Hull

Contract Dates: 6/98–12/99
PI: Professor G. Harries-Jenkins

SCIENTIFIC OBJECTIVES

The scientific objectives of this research were:

- 1) To review the characteristics of effective military leadership styles and strategies in a period of change.
- 2) To carry out a comparative analysis of the policies, problems, and practices of Western European military establishments in ensuring effective leadership.
- 3) To identify and conceptualize models of good national policies and practices in this field.

APPROACH

Initially, two workshops were planned. In the first of these, a small group of technical specialists met to establish a suitable conceptual framework for subsequent comparative analysis. In the second, an extended group of specialists received and reviewed appropriate scientific contributions to the research aims and objectives. Such contributions were to be edited and published as a Final Technical Report.

PROGRESS

The first workshop (planning) was held in Beverley, England in September 1998. Subject areas were identified on the basis of a twin-track strategy whereby theoretically based analysis would be complemented by specific national case studies. The papers designed to implement this strategy were received and reviewed at a second workshop held in Beverley in April 1999. Twelve specialists participated in this meeting. Subsequently, five of those specialists held an informal meeting during the Inter-University Seminar biennial conference in Baltimore, in October 1999, to consider and refine the conclusions to be drawn from the published papers. The Final Technical Report was released on December 31, 1999.

CONTRIBUTION TO BASIC SCIENCE

This research project identified, from a comparative perspective, the fundamental challenges to be faced when seeking to conceptualize theories of military leadership during a period of change. It encouraged those working in the broad field of military sociology to reconsider basic issues of civil-military relationships, of civil-military culture gap, and of managing diversity in the military. In addition, this research project has stimulated further research, as evidenced in publications and conference contributions, enhancing its contribution to basic science.

POTENTIAL APPLICATIONS

The CRMI (Comparative Research in Military Institutions) group of technical specialists reached the following conclusions:

- 1) The tendency in the training of personnel to stress the importance of management styles based on civilian practice, rather than traditional military values, can weaken subsequent leadership in active service operations; and,

- 2) This training shortfall is especially noticeable in the career development of junior NCOs and junior officers.
- 3) In multi-national collaborative operations, leaders, at all rank levels, need to acquire a greater understanding of the cultural complexities inherent in such operations.
- 4) To enhance effectiveness, leaders must be more aware of the problems associated with the management of diversity in the contemporary armed forces.
- 5) The principles of sound military leadership remain unchanged irrespective of alterations in the role and function of the military today.

International Military Education and Training: A Sociological Analysis

Contract: DASW01-95-K-0003

Institution: Northwestern University

Contract Dates: 6/1/98 - 6/30/01

PI: Charles Moskos

SCIENTIFIC OBJECTIVES

The objective of this research is to bridge methodological and theoretical issues found in general social science with those dealing with military organizations. We intended to advance the understanding of intercultural relations between and within large-scale organizations. The specific goal is to specify factors that help or hinder international cooperation among military personnel. As with prior ARI sponsored projects, the research agenda is also subject to direction from senior personnel in the military and U.S. government. The research goals are explicitly dynamic in order to incorporate developments during the period of the research.

APPROACH

Since 1950, some 500,000 international military officers and senior enlisted personnel have received professional training through the International Military Education and Training (IMET) program of the United States. In the post-Cold War era, IMET plays an even more important role with regard to fragile democracies, integrity standards of security officials, multinational operations, and a range of nontraditional missions, (e.g., peacekeeping, humanitarian, and nation building) as well as conventional military concerns. As such, the population is an excellent source of data to study.

The approach is fourfold: (1) research on IMET participants in the United States, (2) research on IMET graduates in their home countries, (3) research on comparable programs in advanced Western democracies, and (4) on-site research in military operations other than war. The methodology will be primarily in-depth interviews with students, graduates, and staff members of professional military education programs.

PROGRESS

The IMET study is in its first phase, but interviews have already been conducted with IMET graduates in Japan, Netherlands, and Israel. In addition, a two-day visit was spent at a British staff college and a two-day visit at the Asia-Pacific Center for Security Studies. Cooperation with the directors of war and staff colleges in the United States has been excellent. Of special note is General Joseph Ralston, the current Vice Chairman of the Joint Chiefs of Staff and NATO commander designate, who has taken a personal interest in the IMET project.

The major accomplishment at this time is the publication of The Postmodern Military: Armed Forces After the Cold War (Oxford University Press, 2000). The editors are Charles C. Moskos, John A. Williams, and David R. Segal. The volume contains chapters (written by local social scientists) on Australia, Denmark, Canada, France, Germany, Israel, Italy, Netherlands, South Africa, and the United Kingdom. This is the first comprehensive work in military sociology in the post-Cold War era.

A second publication will be Charles C. Moskos, The Media and the Military in Peace and Humanitarian Operations, (Chicago: McCormick Tribune Foundation) to be published in March. Kenneth Bacon, head of media relations for the Department of Defense has asked me to make a

Pentagon presentation on the publication on March 15, 2000. In attendance will be the public affair chiefs of the services and major commands.

A third publication goes back to my ARI-sponsored work on race relations. This is Charles C. Moskos, "Diversity in the Armed Forces in the United States," In Joseph Soeters and Jan van der Meulen, eds., Managing Diversity in the Armed Forces: Experiences from Nine Countries (Netherlands: Tiburg University Press, 1999, pp. 13-32).

Another avenue of research was undertaken at the request of the Deputy Chief of Staff for Personnel. This involved a survey (December 1999) of some 450 undergraduates at Northwestern University on a various military enlistment options. The analysis has not yet started for this project. The concern here is to think of way to improve military recruitment.

A final avenue of research is related to the enhancement of democratic civil-military relations. In this regard, the Principal Investigator served as the "special adviser" to Vice President Gore's "Global Forum on Fighting Corruption: Safeguarding Integrity among Justice and Security Officials" (February 24-26, 1999). Because of commitments to other projects, I have not been able to follow-up on this work as some would like.

CONTRIBUTION TO BASIC SCIENCE

The data along with the concepts introduced in this research on comparative military organizations will inform social scientists doing basic research in several areas. One is the role of multicultural communications with formal organizations. A second is the nature of military-media relations in diverse societies. In addition, the research demonstrates the utility of a multi-method approach to sociological issues: survey data, focus groups, interviews, comparative organizational analysis, and participant observation.

POTENTIAL APPLICATIONS

The IMET project addresses one of the most significant concerns of the United States military in cooperation with the armed forces of other countries. Namely, the expansion and engagement with democratic civil-military systems. Also, by examining multi-national cooperation in peacekeeping and humanitarian missions, the project deals with current issues in the deployment of American forces. The fact this study was initiated by the Joint Chiefs of Staff, indicates the centrality of this issue for American national security.

Social And Cultural Dynamics Of American Military Organization

Contract #: DASW01-95-K-0005

Institution: University of Maryland at
College Park

Contract Dates: 3/6/95-9/30/00

PI: David R. Segal & Mady Wechsler Segal

SCIENTIFIC OBJECTIVES

The objectives of this research are: (a) to increase knowledge of the interface between the contemporary American military institution and the broader American society, in order to better understand the dynamics of how civilian institutions impact upon the military and vice-versa; (b) to explore specifically, the interface between the American military and the American family as social institutions, in order to better understand how the family serves as a boundary-spanning institution between the civilian and military sectors of American society; (c) to increase understanding of the behaviors, attitudes, and values of contemporary American military personnel, so that as the military becomes a increasingly diverse institution socio-demographically, human resource management can become increasingly rooted in the scientific understanding of human behavior; and (d) to view the American military institution in the context of more general organizational changes in military institutions and in other nations, in order to gain a better understanding of which changes observed in the American military are unique to the United States and which are a more general phenomena common to the armed forces of western industrial nations.

APPROACH

This research involves both qualitative analysis and statistical modeling of quantitative data on American civilians (including those approaching military age-eligibility), civilian spouses of American military personnel, and American military personnel themselves. This research also involves deriving data from documentary sources on relationships between armed forces and societies in other nations. Three research questions are posed with regard to each of the three populations mentioned, as well as with regard to the cross-national research.

The three primary questions addressed by the research on the American public are: what characteristics predict which young Americans will serve in the military; what are the consequences of having served in the military in terms of occupational status, education, and earnings after reentry to civilian life; and what is the nature of social support for the military missions of the 1990s among the American public?

The three primary questions addressed by our research on military families are: how do the family policies of an organization (in this case the Army) affect the commitment of family members to the organization; what are the effects of military culture and military operations on the families of military personnel; and how do military personnel who are forward deployed or forward stationed maintain contact with their families on the home front?

The three primary questions addressed by our research on military personnel are: what are the basic values of entry-level personnel, and are they compatible with the needs of the military of the future; what are the impacts on the attitudes and behaviors of American soldiers of the range of missions that they performed in the 1990s; and are these attitudes and behaviors compatible with the management of a socio-demographically diverse military force?

The three primary questions addressed by our cross-national research are: what are the social roots of military service in democratic states and how is military service changing as modern states increasingly move from conscription-based forces to volunteer forces; what have been the similarities and differences observed among nations dealing with increased socio-demographic diversity, and particularly with gender integration and sexual orientation integration; and how are other nations experiencing the processes of military down-sizing and base closing?

PROGRESS

In the last year, five journal articles and two book chapters reporting the results of this research were published, two additional articles were submitted and accepted for publication in 2000, and two more articles are being revised for journal publication. In regard to research on the American public, analysis of data on the high school class of 1972, provided most of the first volunteers for post-conscription force and highlighted the importance of propensity to serve, as a predictor of service, for the very first volunteer force cohort (72% of those who served stated such plans while still in high school). Research collaboration with colleagues at the University of Michigan on high school seniors' enlistment propensity and actual enlistment behavior, who graduated between 1975-1997, showed that 70% of male high school seniors reporting high propensity, enlisted within six years of high school graduation. The noted decline in the early 1990s of enlistment propensity was found, almost wholly, to be a result of the decline in propensity of African-Americans, who had been the highest propensity group during the first two decades of the volunteer force and who moved closer to other groups in the 1990s. In addition, enlistment propensity among Hispanic high school seniors was found to be higher among white non-Hispanic seniors and the under-representation of Hispanics in the military was found to be due to their non-completion of high school rate, not their desire to serve. Further, the zero-tolerance policy with regard to illicit drug use in the military has played a major role in extinguishing drug behavior among recruits, but the ban on smoking in entry-level training seems to have led smokers to exclude themselves from the recruitment pool. In addition, two articles have demonstrated the importance of soldier perceptions that the Army is supportive of families, on soldier commitment and morale. Our research has shown, that in one of the Army's most frequently deployed divisions, operational tempo has a negative effect on morale, but not on reenlistment intention, has been submitted for publication in a professional journal.

In the months remaining on this contract, we are completing research on the conditions under which the American public supports the military missions of the 1990s. We are also completing research on the impact of military service on the financial well-being of women veterans. Early in 2000, our book on *The Postmodern Military*, co-edited by Charles Moskos, John Williams, and David Segal, reporting structural changes in the armed forces of a dozen nations, since the end of the Cold War in Europe, will be published by Oxford University Press, and we will continue our study of the downsizing of the Russian Army.

CONTRIBUTIONS TO BASIC SCIENCE

The nature of the human life course has become a major paradigm in the social and behavioral sciences, and our work on both the antecedents and social consequences of military service has helped shape this paradigm. Our work on military families reflects one of the major contemporary research areas in the sociology and psychology of the family: the work-family

interface. Our work has used the Army as a test-bed for many of the theoretical principles in these fields. Likewise, in the area of organizational downsizing, our work on operational tempo in a smaller Army has served as a source of empirical data on what happens to an organization when it becomes smaller while its missions seem to be expanding. Our comparative work has expanded the scope of the field of military sociology, which for most of this century has been primarily the sociological study of the American military. Our work provides a basis for exploring the generalizability of organizational concepts and relationships formerly explored primarily in the context on the United States.

POTENTIAL APPLICATIONS

Three potential applications of our research have become evident: the translation of results of research on military families into guidance on how to support families of deployed soldiers; the impact of our research on the relationship between enlistment propensity and actual enlistment behavior on the recruitment strategies policy debate; and the attention paid by the policy community, including the Office of the Secretary of Defense, the Defense Science Board, and the General Accounting Office, to our findings on the dimensions and importance of the quality of life in the military. Other life-course research can contribute to the development of programs to ease the transition from military to civilian life. Our research on the use of modern communication technologies by deployed soldiers can help guide policy-makers both in maximizing the positive impacts of these technologies on soldier morale and in considering the information security problems associated with the use of these technologies. Our research on the attitudes and behaviors of military personnel can help inform Army doctrine on what kinds of soldiers should be used in stability operations, and what kinds of special training they may require. Further, our cross-national research allows us to identify human resource management strategies that have been implemented in other nations that might be useful here, or strategies that have been considered here but have already been shown in other contexts not to be effective.

Summary of Research on Army Culture

Contract #: DASW01-98-M-1868
Institution: University of Ottawa

Contract Dates: 5/98-1/31/00
PI Name: Donna Winslow

SCIENTIFIC OBJECTIVES

The goal of this research is to produce an analysis of the literature pertaining to Army culture. It will assist in understanding the relationship between the Army's organizational culture (basic assumptions, spirit, beliefs, and the characteristic ways of doing things, that are shared by the members of the organization) in order to better interpret the role these elements play in the functioning of the Army. In addition, we will analyze methods used to study organizational culture and ways of modifying that culture.

APPROACH

The analysis will examine the material available in three fields of study: anthropology, organizational studies, and military sociology. The first step was the production of an annotated bibliography of written documents pertinent to the theme of military culture. The basis for selection was each document's relevance to the understanding of Army culture and in particular the three following aspects: 1) the definition of Army culture; 2) the observation of Army culture; and, 3) the change of Army culture. Drawing upon these documentary sources an analysis of the literature and its relevance to the understanding of Army culture will be produced. This analysis will then form the basis for developing a briefing package for commanders on "Army culture."

PROGRESS AND PLANS

In June 1999, we completed an annotated bibliography on military culture. We looked at the research in the fields of anthropology, organizational studies, and sociology. Because there has been so much written in the area of culture and organizations, we limited ourselves to theses and works published in English after 1985. 1985 was our starting date because of the explosion in organizational culture studies, which took place in the 1980's. We selected material that helped in the understanding of Army culture, methods that would be useful in studying Army culture, and discussions of ways to change organizational culture. In order to have comparative material, we included some references to other service cultures, that is, Marine, Navy, and Air Force cultures. We also examined work on the culture of "uniformed organizations" such as the police. Most references refer to Western, particularly US organizations, although we did include relevant material on other national cultures such as the recent work on the Israeli Army. Using "keyword," "shelve," and "snowball" searches of databases, 6768+ matches were found, of which 2012 were considered relevant. Out of these, 327 articles, theses and books were selected for the annotated bibliography.

Since that time, we have been examining the relevant literature and writing a paper on what can be understood about Army culture from the literature. This analysis is broken into four parts. The first part, discusses interest in the culture concept in organizational and military studies and the relevance of the culture concept in furthering our understanding of the functioning of the Army. The second part, describes what different theoretical schools (rationalism, functionalism, and symbolism) mean by culture and how they approach the study of

culture in organization. The third part examines Army culture, as it would be described by these major theoretical traditions. The fourth and final part, describes the impact of external (particularly the impact of values and trends in the larger civilian environment) and internal factors on change in organizations in general and in the Army in particular.

Finally, a briefing package for Army commanders will be prepared drawing upon the extensive review of the literature. This package will consist of a computer based presentation, following the three axes outlined above: 1) the definition of culture; 2) the observation of culture; and, 3) the change of culture. Each axis will be described as it pertains to issues pertinent to command of Army units. The briefing package will be field tested and modified according to the feedback received.

CONTRIBUTION TO BASIC SCIENCE

The research will outline different theoretical approaches to understanding Army culture. It will draw conclusions on how culture can affect the functioning of an Army unit. In addition, it will describe how external forces and internal forces can change the culture of an organization such as the Army. Further, it will address the impact of civil military relations on Army culture.

POTENTIAL APPLICATIONS

This analysis will serve as the basis for developing a briefing package for Army commanders on military culture and how this culture can affect the functioning of their unit, and how they in turn can affect the culture of the units they command. What is relevant for an Army commander is the knowledge that culture is much more than leadership or a set of values. It can, however, be used to reinforce certain values. How does culture affect performance and discipline in a unit? How can culture affect command climate and unit morale? From the literature, it is possible to identify several ways of "measuring" Army culture, that is methods, which can be used to observe behaviors and social structures within a unit. Finally, it is important to understand how forces external (particularly the interface with civilian society) and internal to an organization can change an organization's culture.

RACO RESEARCH OBJECTIVE #4:

Provide an understanding of cognitive processes and affective basis of soldier behavior.

This category of research deals with the relationships between individual differences in soldier cognition and affective behavior.

An Emotional Cognitive Architecture for Synthetic Forces

Contract #: DASW01-98-K-0008
Institution: USC/ISI

Contract Dates: 9/1/98- 8/31/01
PI: Randall W. Hill, Jr.

SCIENTIFIC OBJECTIVES

- 1) Contribute to the understanding of the functional role of emotion and stress in battlefield decision-making.
- 2) Investigate the use of emotion in creating believable Command and Control (C2) agents for Joint Synthetic Battlespaces (JSB).
- 3) Investigate the role of emotion in guiding an artificial intelligence planning system to support more effective, flexible, and coherent decision-making.

APPROACH

This effort builds on a C2 planner we developed to model Battalion and Company level operations in a JSB. The C2 planner generates, executes and repairs plans that are carried out by Soar-based synthetic force agents. To model the role of emotion and stress in decision-making, we will extend the C2 planner by incorporating a theory of affective moderators on the decision-making process.

The rationale for this approach builds on two theoretical assumptions: that emotions are functional (they play a key role in normal decision-making); and emotions are related to a person's goals (specifically, they characterize the relationship between goals and the current environment). Oatley (1992) summarizes the functional argument as follows: (a) human action involves multiple, competing goals; (b) actions are taken in the context of limited resources and imperfect information; and, (c) much of human action is undertaken jointly with others. Consequently, emotions evolved to manage this process by organizing transitions and establishing priorities. Ortony, Clore, and Collins (1988), Lazarus (1991) and others argue strongly for the importance of understanding a person's goals in order to make sense of the myriad of circumstances that evoke an emotional response. Wells and Matthews (1994) make similar arguments with regard to explaining stress effects. All of these authors view emotions and stress effects as arising from a form of goal-based situation assessment. "Emotions are complex, patterned, organismic reactions to how we think we are doing in our ... efforts to survive and flourish and to achieve what we wish for ourselves" (Lazarus, 1991 pg. 6). Some artificial intelligence researchers have developed computational accounts of emotional inspired by these views (Elliott, 1992; Neal Reilly, 1996).

Our approach will implement a model of how emotions arise from a process of goal-based situation assessment, and how they affect goal prioritization and action selection in the C2 planner. The effects of appraisal and planning will be evaluated in the context of Army Aviation C2 operations. This work builds on and significantly extends the computational approaches of Elliott and Neal Reilly.

PROGRESS

Last year's effort focused on: (a) extending the initial prototype model of emotional reasoning; and (b) building a simple test-bed application to support demonstration, validation,

and experimentation of the behavioral model. The modeling extensions addressed the problem of how to account for the dynamics of an agent's emotional response: responses vary in intensity and change over time. This was conceptualized in terms of the utility of an agent's goals and the agent's perception of their probability of attainment, mediated by the current plans in memory. The test-bed interfaces our planning system and model of emotional reasoning with a virtual environment containing human-like aviators (developed by another research group at ISI). The test-bed supports some simple peer-to-peer interactions between agents, and enables some modeling of individual differences across agents through a crude set of "personality" parameters.

CONTRIBUTIONS TO BASIC SCIENCE

- Jonathan Gratch wrote a technical paper entitled, "Emile: Marshalling Passions in Training and Education," which will appear in the Fourth International Conference on Autonomous Agents (Agents2000).
- Jonathan Gratch wrote an abstract called, "Modeling the interplay between emotion and decision making" which will appear as a paper in the Ninth Conference on Computer Generated Forces and Behavioral Representation (CGF-2000).
- Jonathan Gratch presented the emotional modeling approach as an invited speaker to a conference on virtual reality at Brown University (VIRTUALLY2K).
- Jonathan Gratch wrote a technical paper entitled, "Why You Should Buy an Emotional Planner," that appeared in the Third International Conference on Autonomous Agents '99 Workshop on Emotion-based Agent Architectures (EBAA99).
- Briefed emotional model to various organizations including Mike Macedonia at STRICOM, Larry Willis at DARPA, Bill Swartout at the Institute for Creative Technologies

POTENTIAL APPLICATIONS

Command and Control (C2) planning agents for Joint Synthetic Battlespaces. It should be possible to model the decision-making of C2 staffs under various conditions that evoke emotional responses. This will add realism and variation to virtual and simulation training environments.

Believable agents. In applications such as virtual training environments, emotion can make an intelligent tutor or virtual teammate appear more believable, thus adding realism to the experience.

Games. There is a close relationship between games and simulation-based training. There are numerous possibilities for developing realistic agents for games based on this technology.

Uncertainty Monitoring and Information Comprehension

Contract #: DASW01-98-K-0006
Institution: Morris Brown College

Contract Dates: 10/1/98 - 7/31/00
PI: David Washburn

SCIENTIFIC OBJECTIVES

This project is comprised of three experiments designed to accomplish four objectives: (a) to identify individual and group differences in the ability to monitor levels of psychological uncertainty and to assess its role in judgment and decision making; (b) to determine correlations between the meta-cognitive ability to monitor uncertainty and other mental abilities, individual or group characteristics, and physiological measures of interest to the Army; (c) to assess the influence of training, time-pressure, and fatigue on uncertainty monitoring ability; and (d) to increase our understanding of the interaction between uncertainty and meta-cognition on decision making by producing a computational model of decision making that includes components of both uncertainty and monitoring, and by producing analyses of uncertainty monitoring and correlated mental abilities so as to determine which cognitive skills and processes support or give rise to others.

APPROACH

Volunteers were tested on a battery of cognitive tasks to provide measures of attention skills, situation awareness, temperament, and other mental abilities. Additionally, a test of responsiveness to one's own uncertainty was administered. The task used psycho-physical methods empirically to define each individual's region of uncertainty, and then determined the degree to which each person monitors and responds adaptively to uncertainty. Relationships between this metacognitive ability and other mental or personality characteristics are to be identified. Subsequently, various training procedures will be attempted, to improve the adaptive response to uncertainty.

PROGRESS

Software development. Since the project began, we have developed all software for the assessments to be used in this experiment. The battery of tasks include: automated versions of eight personality/temperament questionnaires, a subset of the Assessment Software for Attention Profiles (ASAP) tasks, and a streamlined version of our test for uncertainty in psycho-physical judgment task.

Pilot research. The original ASAP battery was designed to identify individual differences in attention and executive-function abilities across three-to-six sub-scales or dimensions. Administration of this battery required over an hour per participant. Additionally, the original psycho-physical uncertainty task required almost an hour. For each participant, the task had to overcome the difficulty of a perceptual discrimination (a dense/sparse judgment) to the point in perceptual space where uncertainty could be operationally defined. Moreover, this same task had to introduce participants to the escape response as a means of adapting to uncertainty. Because the personality and temperament measures also required about 30 minutes to complete, we made a number of iterations of modification-and-testing of the assessment devices. The current battery requires about 60 minutes to complete, a duration tolerated by research volunteers.

Experiment 1 progress. To date, we have tested 54 volunteers on the battery of tasks for Experiment 1, in which we will make draw the primary conclusions from this project. Recruitment of participants has been slow. The target number of participants for this study (at least 100) should have completed testing by mid-February of 2000.

CONTRIBUTIONS TO BASIC SCIENCE

These data will illuminate the basic nature of meta-cognitive abilities and their role in judgment and decision making. The lines between the cognitive constructs of attention, working memory, executive function, and intelligence are becoming increasingly blurred within the literature, suggesting that it is impossible adequately to investigate one component without also measuring many others. The present study promises to relate one particular aspect of executive function (uncertainty monitoring) to numerous better-understood constructs like attention and personality. These inter-construct relationships may in turn account for the pronounced individual differences and group (e.g., children versus adults, adults versus elderly, normally developing versus ADHD) that are observed in meta-cognitive ability.

POTENTIAL APPLICATIONS

The data produced here will have numerous Army-relevant benefits, including:

- (a) A better model of information comprehension and decision making will be produced for predicting behavior under conditions of uncertainty. The empirically grounded assumption that drives this study is that different individuals make different decisions under comparable conditions of uncertainty, as a function of whether or not the individuals are monitoring their uncertainty and factoring this into the judgment.
- (b) Understanding the monitoring of uncertainty will guide the development of instrumentation and feedback to the soldier can be tailored to provide the right kind of guidance to each individual under each condition. Providing more information will be of little help for the soldier who is not monitoring her/his uncertainty (i.e., who is confident but wrong about a decision).
- (c) Selection for duties that are likely to involve uncertainty would benefit from an index of each soldier's sensitivity to uncertainty--an assay for which the distribution characteristics and psychometric properties have been identified.
- (d) In profiling mental abilities across constructs, a better understanding can also be achieved of the cognitive abilities that distinguish good leaders, communicators, teachers, sentries, and so forth from their less gifted peers.
- (e) Training procedures will be recommended that effectively and efficiently improve uncertainty monitoring and responsiveness.
- (f) The variables typically encountered by the soldier (fatigue, time-pressure) are likely to have quite different effects on performance and self-regulation of easy tasks versus those that create uncertainty. It is critical to identify these interactions so as to be able better to predict and prevent critical errors in judgment.

